INTERNATIONAL VLBI SERVICE
FOR GEODESY AND ASTROMETRY

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INTERNATIONAL VLBI SERVICE FOR GEODESY AND ASTROMETRY
2004 ANNUAL REPORT
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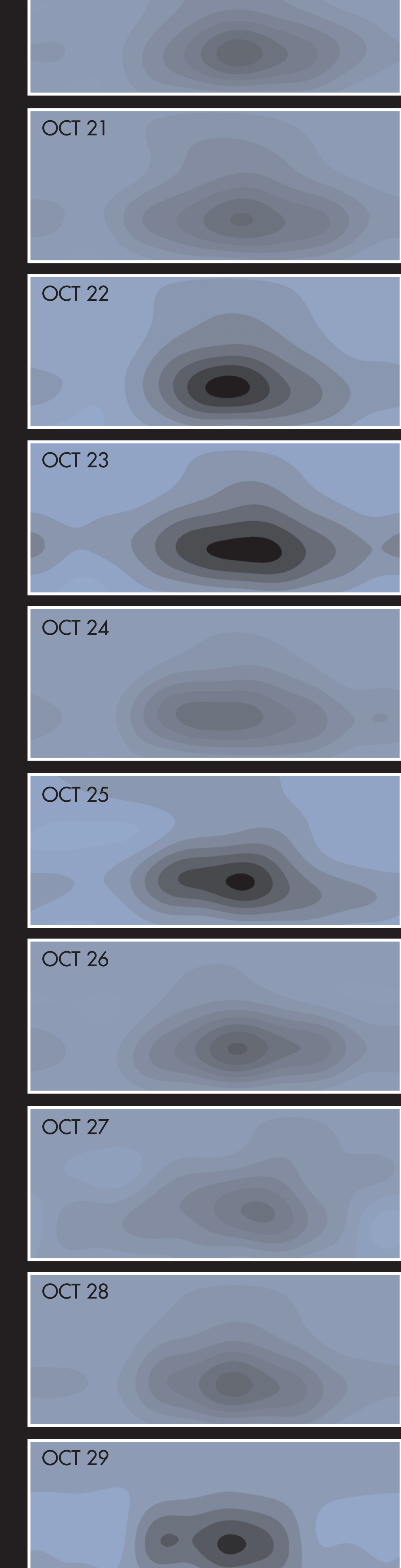
INTERNATIONAL VLBI SERVICE FOR GEODESY AND ASTROMETRY

Annual Report

Edited by
D. Behrend and K.D. Baver

IVS Coordinating Center
February 2005

2004



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On the cover: evolution of the ionospheric total electron content for 10 days of the CONT02 continuous VLBI campaign in in October 2002 (Courtesy: Rüdiger Haas). The maps cover an area from 180°W to 180°E sun-fixed longitude (horizontal axis) and from 30°S latitude up to the North pole (vertical axis). For more details see the Analysis Center report of the Onsala Space Observatory in this volume.

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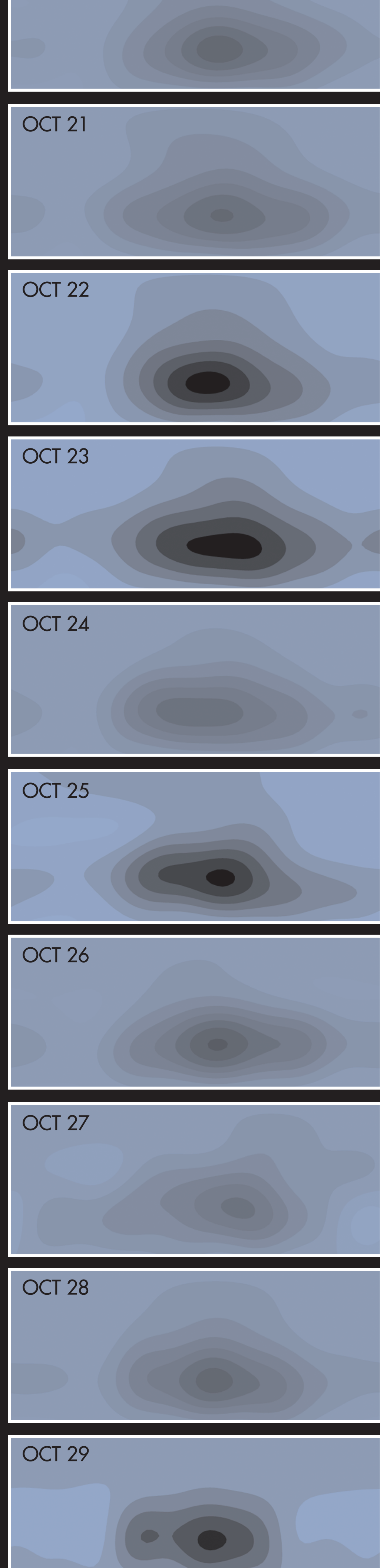

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Preface

This volume of reports is the 2004 Annual Report of the International VLBI Service for Geodesy and Astrometry (IVS). The individual reports were contributed by VLBI groups in the international geodetic and astrometric community who constitute the permanent components of IVS.

The IVS 2004 Annual Report documents the work of the IVS components for the calendar year 2004, our sixth year of existence. The reports describe changes, activities, and progress of the IVS. Many thanks to all IVS components who contributed to this Annual Report.

With the exception of the first section (described below), the contents of this Annual Report also appear on the IVS web site at

`http://ivscc.gsfc.nasa.gov/publications/ar2004`

This book and the web site are organized as follows:

- The first section contains general information about IVS, a map showing the location of the components, information about the Directing Board members, and the annual report of the IVS Chair.
- The second section contains a special report about combination studies using the CONT02 campaign.
- The next seven sections hold the reports from the Coordinators, and the reports from the IVS Permanent Components: Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers.
- The last section includes reference information about IVS: the Terms of Reference, the lists of Member and Affiliated organizations, the IVS Associate Member list, a complete list of IVS components, the list of institutions contributing to this report, and a list of acronyms.

Table of Contents

About IVS

IVS Organization

OBJECTIVES

IVS is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. The goals are:

1. To provide a service to support geodetic, geophysical and astrometric research and operational activities.
2. To promote research and development activities in all aspects of the geodetic and astrometric VLBI technique.
3. To interact with the community of users of VLBI products and to integrate VLBI into a global Earth observing system.

The IVS

- Interacts closely with the IERS, which is tasked by IAU and IUGG with maintaining the international celestial and terrestrial reference frames (ICRF and ITRF),
- coordinates VLBI observing programs,
- sets performance standards for the observing stations,
- establishes conventions for data formats and products,
- issues recommendations for analysis software,
- sets standards for analysis documentation,
- institutes appropriate product delivery methods in order to insure suitable product quality and timeliness.

REALIZATION AND STATUS OF IVS

IVS consists of

- 30 Network Stations, acquiring high performance VLBI data,
- 3 Operation Centers, coordinating the activities of a network of Network Stations,
- 6 Correlators, processing the acquired data, providing feedback to the stations and providing processed data to analysts,
- 6 Data Centers, distributing products to users, providing storage and archiving functions,
- 21 Analysis Centers, analyzing the data and producing the results and products,
- 7 Technology Development Centers, developing new VLBI technology,
- 1 Coordinating Center, coordinating daily and long term activities.

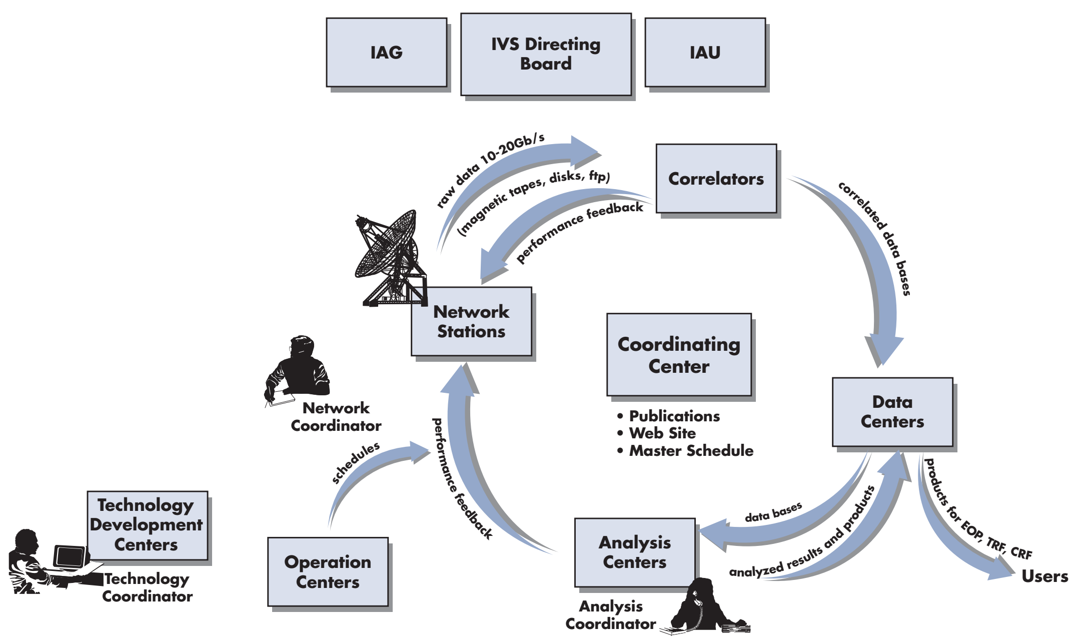
Altogether

- 74 Permanent Components, representing 37 institutions in 17 countries,
- ~250 Associate Members.

In addition the IVS has:

- Directing Board, determining policies, standards and goals; the board is composed of 15 members (elected and ex officio), including
- Coordinators for the network, analysis and technology.

ORGANIZATION OF INTERNATIONAL VLBI SERVICE



IVS MEMBER ORGANIZATIONS

The following organizations contribute to IVS by supporting one or more IVS components. They are considered IVS Members. Listed alphabetically by country.

Organization	Country
Geoscience Australia	Australia
University of Tasmania	Australia
Vienna University of Technology	Austria
Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Space Geodynamics Laboratory	Canada
Geodetic Survey Division, Natural Resources Canada	Canada
Dominion Radio Astrophysical Observatory	Canada
Canadian Space Agency	Canada
Universidad de Concepción	Chile
Universidad del Bío Bío	Chile
Universidad Católica de la Santísima Concepción	Chile
Instituto Geográphico Militar of Chile	Chile
Chinese Academy of Sciences	China
Observatoire de Paris	France
Observatoire de Bordeaux	France
Deutsches Geodätisches Forschungsinstitut	Germany
Bundesamt für Kartographie und Geodäsie	Germany
Geodetic Institute of the University of Bonn	Germany
Forschungseinrichtung Satellitengeodäsie, TU-Munich	Germany
Istituto di Radioastronomia CNR	Italy
Agenzia Spaziale Italiana	Italy
Geographical Survey Institute	Japan
National Institute of Information and Communications Technology	Japan
National Astronomical Observatory of Japan	Japan
National Institute of Polar Research	Japan
Norwegian Defence Research Establishment	Norway
Norwegian Mapping Authority	Norway
Astronomical Institute of St.-Petersburg University	Russia
Institute of Applied Astronomy	Russia
Hartebeesthoek Radio Astronomy Observatory	South Africa
Instituto Geografico Nacional	Spain
Chalmers University of Technology	Sweden
Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine
Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
NASA Goddard Space Flight Center	USA
U. S. Naval Observatory	USA
Jet Propulsion Laboratory	USA

IVS AFFILIATED ORGANIZATIONS

The following organizations cooperate with IVS on issues of common interest, but do not support an IVS component. Affiliated Organizations express an interest in establishing and maintaining a strong working association with IVS to mutual benefit. Listed alphabetically by country.

Organization	Country
Australian National University	Australia
University of New Brunswick	Canada
Max-Planck-Institut für Radioastronomie	Germany
FÖMI Satellite Geodetic Observatory	Hungary
Korea Astronomy Observatory	Korea
Joint Institute for VLBI in Europe (JIVE)	Netherlands
Westerbork Observatory	Netherlands
Aukland University of Technology	New Zealand
Central (Pulkovo) Astronomical Observatory	Russia
National Radio Astronomy Observatory	USA

PRODUCTS

The VLBI technique contributes uniquely to

- Definition and realization of the International Celestial Reference Frame (ICRF)
- Monitoring of Universal Time (UT1) and length of day (LOD)
- Monitoring the coordinates of the celestial pole (nutation and precession)

Further significant products are

- All components of Earth Orientation Parameters at regular intervals
- Station coordinates and velocity vectors for the realization and maintenance of the International Terrestrial Reference Frame (ITRF)

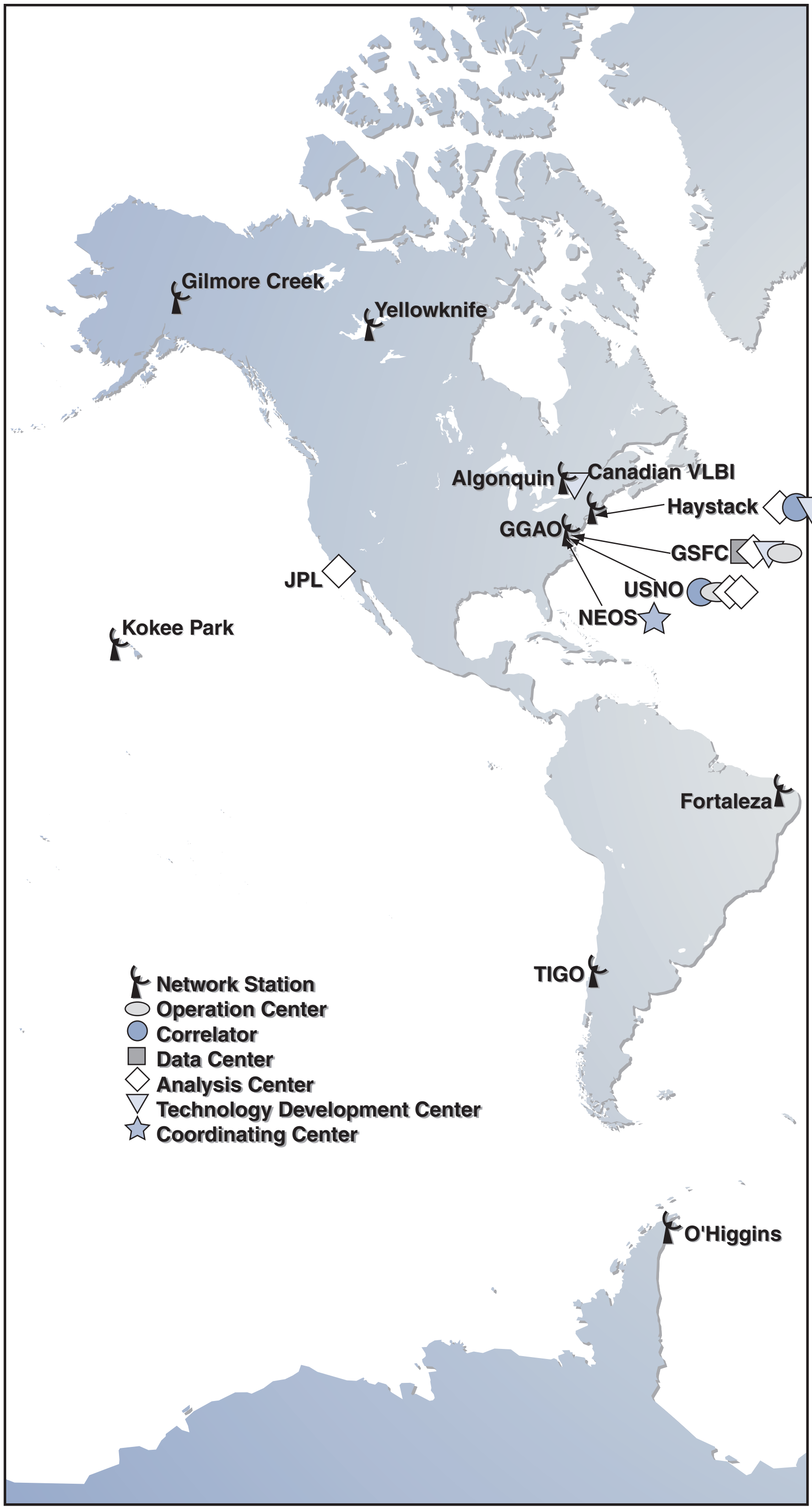
All VLBI data and results in appropriate formats are archived in data centers and publicly available for research in related areas of geodesy, geophysics and astrometry.

IVS Component Map

IVS COMPONENTS BY COUNTRY

Australia	2
Austria	1
Brazil	1
Canada	3
Chile	1
China	3
France	3
Germany	8
Italy	7
Japan	12
Norway	3
Russia	6
South Africa	1
Spain	1
Sweden	3
Ukraine	2
USA	17
Total	74

A complete list of IVS Permanent Components is in the IVS Information section of this volume.



Ny Ålesund
Onsala
FFI
Svetloe
IAA
AIStPbU
GIUB
BKG
FGS(BKG,GIUB)
MAO
DGFI
Wettzell
Paris
TU Vienna
Zelenchukskaya
Bordeaux
Medicina
Simeiz
CNR
Yebes
Matera
Noto
Nanshan
Mizusawa
Tsukuba
Kashima34
Seshan
CRL
Shanghai
Kashima 11
Koganei
Hartebeesthoek
GA
Hobart
Syowa

IVS Directing Board

NAME: Wolfgang Schlüter

AFFILIATION: Bundesamt für Kartographie und Geodäsie, Germany

POSITION: Chair and Networks Representative

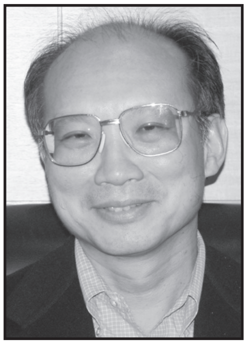
TERM: Feb 2003 to Feb 2007

NAME: Ed Himwich

AFFILIATION: NVI, Inc./ Goddard Space Flight Center, USA

POSITION: Network Coordinator

TERM: permanent

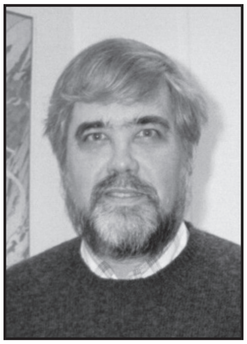


NAME: Chopo Ma

AFFILIATION: NASA Goddard Space Flight Center, USA

POSITION: IERS Representative

TERM: ex officio



NAME: Kerry Kingham

AFFILIATION: U.S. Naval Observatory, USA

POSITION: Correlators and Operation Centers Representative

TERM: Feb 2003 to Feb 2007

NAME: Zinovy Malkin

AFFILIATION: Institute of Applied Astronomy, Russia

POSITION: Analysis and Data Centers Representative

TERM: Sept 2003 to Feb 2005

NAME: Yasuhiro Koyama

AFFILIATION: National Institute of Information and Communications Technology, Japan

POSITION: At Large Member

TERM: Feb 2001 to Feb 2005

NAME: Franco Mantovani

AFFILIATION: CNR Bologna, Italy

POSITION: At Large Member

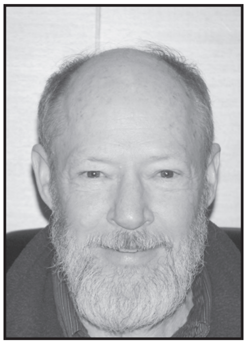
TERM: Sept 2003 to Feb 2005

NAME: Shigeru Matsuzaka

AFFILIATION: Geographical Survey Institute, Japan

POSITION: Networks Representative

TERM: Feb 2003 to Feb 2007

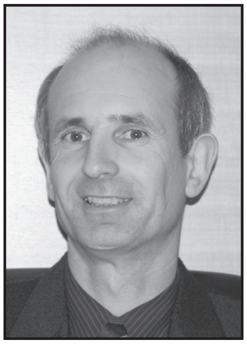


NAME: Arthur Niell

AFFILIATION: Haystack Observatory, USA

POSITION: Techology Development Centers Representative

TERM: Feb 2001 to Feb 2005



NAME: Axel Nothnagel

AFFILIATION: University of Bonn, Germany

POSITION: Analysis Coordinator

TERM: permanent

NAME: William Petrachenko

AFFILIATION: National Resources Canada, Canada

POSITION: At Large Member

TERM: Feb 2003 to Feb 2005

NAME: Harald Schuh

AFFILIATION: Vienna University of Technology, Austria

POSITION: IAG Representative

TERM: ex officio

NAME: Nancy Vandenberg

AFFILIATION: NVI, Inc./ Goddard Space Flight Center, USA

POSITION: Coordinating Center Director

TERM: ex officio

NAME: Patrick Wallace

AFFILIATION: Rutherford Appleton Laboratory, UK

POSITION: IAU Representative

TERM: ex officio

NAME: Alan Whitney

AFFILIATION: Haystack Observatory, USA

POSITION: Technology Coordinator

TERM: permanent

IVS Chair's Report

Wolfgang Schlüter
Bundesamt für Kartographie und Geodäsie, Germany

With the 2004 Annual Report (AR) the International VLBI Service for Geodesy and Astrometry (IVS) presents its 6th Annual Report since its beginning. Even if paper versions appear to be old-fashioned when compared to the e-media which are available today, I think it is still a very valuable document—not only for the IVS Associate Members, but also for external, interested scientists showing the progress of the entire community over time and providing a lot of information about all components. I thank everybody for contributing his work during the year and preparing a report. Timely appearance of the AR is highly appreciated, because it maintains the AR as a real information exchange tool for the community and related groups. Making the AR available in due time is always an ambitious goal and I thank the editors for the timely release.

In 2004 IVS again was able to increase its productivity with respect to previous years. This can be seen by the amount of observations expressed in session days (per year) and in station days (per year). Both parameters are shown in Figure 1 for the time period from 1999 to 2005. In 2004 IVS observed 192 session days, which means that (on average) every other day or more frequently a full day session was carried out and VLBI products were generated. This does not include the Intensive observations, which are now observed daily.

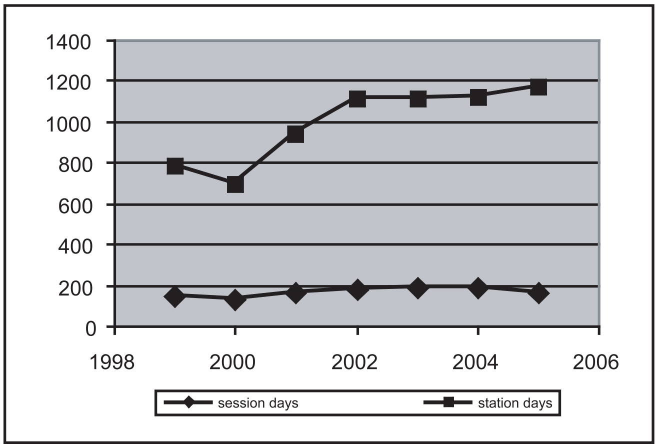


Figure 1. Increase of observations since 1999

Figure 2 depicts the contributions of the stations with more than one 24h-observation session a month. It shows that the load for the stations varies significantly due to various reasons. One reason is the fact that some stations are not only involved in IVS observing sessions but also in radio astronomy projects. Nevertheless, every station day counts and each contribution is highly appreciated. The success of IVS is the sum of all contributions from all components. I would like to express my sincere gratitude to everybody in the community, in particular to the staff of the network stations that carry the load of doing the observations day and night.

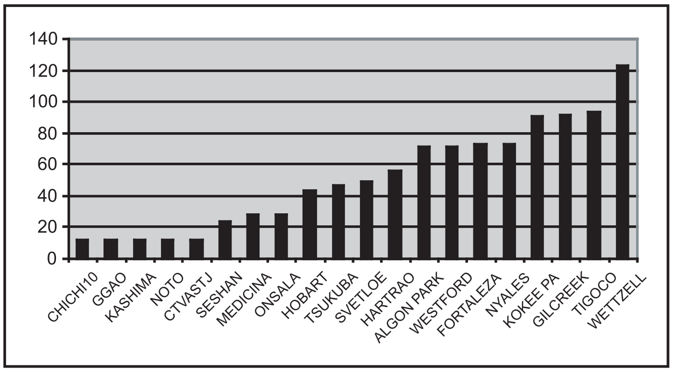


Figure 2. Stations with 12 or more sessions in 2004

New Components and Members

The Institute of Applied Astronomy (IAA), St. Petersburg, Russia, placed a proposal for Zelenchukskaya to become an IVS Network Station. Zelenchukskaya is located in the Caucasus. The IVS Directing Board approved the proposal and highly appreciated the contribution. I would like to express my thanks to the Institute for Applied Astronomy and I wish a successful participation in the IVS observing program.

Professor Sergei Gulyaev placed a request for the Earth and Oceanic Science Research Institute of the Auckland University of Technology to become an IVS Affiliated Organization member. The IVS Directing Board has accepted the proposal. I thank them for their willingness to cooperate with IVS.

Progress in 2004

A lot of progress has been made again in 2004. Here I would like to mention some aspects of general importance.

Our IVS web pages show up in a new design. A small group, coordinated by Nancy Vandenberg, worked out the new web pages, which are very informative and easy to handle. Congratulations for the good work.

IVS participated in the IERS Pilot Project. The prime goal was to set up procedures for combination with other geodetic techniques and to demonstrate the potential of combination. Thanks to the Analysis Coordinator Axel Nothnagel for coordinating the IVS contribution. Some inconsistencies were detected, such as wrong antenna offsets at some stations, which diminished the quality of the results. Now, with corrected offset values, the solutions have obviously improved.

Two steps in technology improvements have been made. The transition from tape drives to digital recording systems such as the Mark 5A and K5 has been performed within a very short period of time. Today most of the stations and in particular the correlators employ Mark 5A and K5 recording systems. Observations recorded with K5 and Mark 5 in one session can be combined in the correlation procedures after format conversion. The digital recording systems improved and tremendously accelerated the correlation process. e-VLBI technology moved from the experimental stage closer and closer to a routine operation. The progress was strongly supported by the Technology Development Centers at MIT Haystack, USA, and NICT, Japan.

Key Events in 2004

In February 2004, we had the 3rd General Meeting in Ottawa, Canada, combined with an Analysis Workshop and a Directing Board Meeting. The keynote was "VLBI: Today's Results and Tomorrow's Vision". All speakers were encouraged to address the results of today and to consider possible future directions. The meeting was a very good basis for the IVS Working Group 3, which is tasked to prepare a vision paper about future VLBI technologies. The Local Organizing Committee at Natural Resources Canada, chaired by Calvin Klatt, did a great job and made the stay during the cold season in Canada very pleasant.

The 3rd e-VLBI Workshop—in combination with a working meeting of Working Group 3 and an IVS Directing Board meeting—was held in Makuhari, Japan, in October. The National Institute of Information and Communications Technology (NICT) supported the meeting, which was very well organised by Yasuhiro Koyama.

Summary information about all the events and activities is available and published in the Newsletters 8, 9 and 10. The Newsletters are an excellent media to transfer the information to everybody. The editor team—Nancy Vandenberg, NVI/Goddard Space Flight Center; Hayo Hase, BKG/TIGO and Heidi Johnson, MIT Haystack—presented interesting and up-to-date information.

Changes in the Directing Board in 2004

Since Harald Schuh, Vienna University of Technology, Austria, was nominated by the IAG to be the IAG representative on the IVS Directing Board, the board nominated Zinovy Malkin, Institute for Applied Astronomy, St. Petersburg/Russia to become the Analysis and Data Centers representative till the end of the term (February 2005). The open at large position, in turn, was filled by the board by electing Franco Mantovani, CNR Bologna/Italy till the end of the term. The election of the Analysis and Data Centers and of the Technology Development Centers representatives by the IVS Associate Members took place in January 2005. The Election Committee —Kerry Kingham (chair), Nancy Vandenberg and Shigeru Matzusaka—started the election procedure in November/December. The election of the three at large positions by the Directing Board was also held in January 2005. The elected board members will begin their terms in 2005.

Chopo Ma and Axel Nothnagel are nominated as IVS representative on the IERS Governing Board. Congratulations to Chopo Ma: he was elected Chair of the IERS. Chopo is also nominated as the IVS representative in the IAG Commission 1 (global reference frames).

I regret to inform you that Nancy Vandenberg is reducing her activities in our community. Dirk Behrend has been employed and will take over Nancy's part after a transition period. So far Nancy's contributions and experiences are of extreme importance for IVS, and I thank her for supporting IVS and introducing Dirk into the business. I would like to welcome Dirk to our community. Dirk has VLBI experience; he worked in a European VLBI Project led by James Campbell. I thank all board members for their active work and for the good collaboration.

Special Reports

Combination Studies Using the CONT02 Campaign

Daniela Thaller, Manuela Krügel, Detlef Angermann, Markus Rothacher, Ralf Schmid, Volker Tesmer

Abstract

This report gives an overview of the combination studies performed by the Forschungseinrichtung Satellitengeodäsie TU München (FESG) and the Deutsches Geodätisches Forschungsinstitut (DGFI) based on the data of the IVS CONT02 campaign. The presented results demonstrate the high potential of a combination of VLBI, GPS and SLR data.

1. Introduction

The 15-days CONT02 campaign of the International VLBI Service for Geodesy and Astrometry (IVS) was used for various comparison and combination studies together with data from other space geodetic techniques. Due to a broad spectrum of common parameters, the studies mainly focussed on the combination of VLBI and GPS. As both techniques make use of microwave signals, identical tropospheric parameters, i.e., zenith delays and horizontal gradients, can be estimated from the VLBI and GPS data for each observing station and can be combined together with the station coordinates and Earth orientation parameters (EOP). In view of a combination with other observing techniques, one big advantage of the CONT02 campaign compared to other VLBI sessions can be seen in the continuous availability of eight observing stations for the whole time span. The participating stations were Algonquin Park, Gilmore Creek, Hartebeesthoek, Kokee Park, Ny-Alesund, Onsala, Westford and Wettzell. All stations are equipped with a permanent GPS antenna and the appropriate local tie information is available (for Ny-Alesund see Steinforth et al. 2003; else, ITRF2000 local ties are available, see Altamimi et al. 2002). The situation is much worse regarding the co-location of VLBI and SLR, because only two of the eight observing VLBI stations can be used, namely Wettzell and Hartebeesthoek. Therefore, a stable combination of these reference frames can only be realized via GPS-SLR co-locations.

2. Data and Processing

In a first step, daily normal equations for each technique were generated for the time span of CONT02, i.e. October 16-30, 2002. The analysis of the VLBI data was done at DGFI using the software OCCAM (Titov et al. 2001), and the GPS analysis was performed at FESG using the Bernese GPS Sofware 5.0 (Hugentobler et al. 2004). It is important to mention that both software packages were prepared in such a way that identical a priori models and identical parameterizations could be used for these special studies. This is crucial for a rigorous combination on the normal equation level and to ensure that the results are identical to those obtained by a combination on the observation level. The SLR solution was also processed with the Bernese GPS Software 5.0, including all Lageos-1 and Lageos-2 data. In view of an inter-technique combination it is a big advantage that any inconsistencies between the techniques due to different models and parameterizations are completely avoided, although the SLR-only solution is probably not of highest quality.

Table 1 summarizes the temporal resolution and the type of parameterization that were chosen for the estimated parameters and the results are presented in the following. This results in a large amount of parameters, especially due to the hourly estimation of Earth rotation parameters and tropospheric zenith delays (ZD). The corresponding number of parameters for each technique and each parameter type is given in Table 2 together with the number of observations that are available for the two weeks. The original number of parameters includes, among others, phase ambiguities (GPS) and orbit parameters (GPS and SLR). Let us point out that the number of GPS observations exceeds that of the other techniques by orders of magnitude, but so does the number of parameters that have to be estimated from these observations. At the beginning of the CONT02 analysis, a lower temporal resolution, i.e., two hours, was chosen for the ERP and tropospheric zenith delays. The corresponding analyses and results are documented in Thaller et al. 2005 and Krügel et al. 2004. Based on these results, the temporal resolution was doubled in order to allow also fast changing features to be grasped, especially in the tropospheric delays.

Table 1. Temporal resolution and parameterization

Station coordinates	daily	constant
ERP	1 hour	piece-wise linear
Nutation angles	daily	piece-wise linear
Tropospheric ZD	1 hour	piece-wise linear
Tropospheric gradients	daily	constant

Table 2. Statistical information for a 14-days solution

	VLBI	GPS	SLR
# stations	8	153	23
# observations	46682	5935760	5088
# parameters (original)	3942	104584	1114
# station coordinates	24	459	69
# tropospheric parameters	2879	2929	-
# EOP	1015	1015	1015

3. Combination Results

Let us now discuss each of the three types of parameters that were estimated from VLBI, GPS and SLR. To begin with the Earth orientation parameters, the most important contribution of VLBI is UT1-UTC as well as the nutation offsets, because VLBI is the only technique to determine these two parameter types. The satellite techniques can only determine the corresponding rates. As an example, the hourly UT1-UTC values estimated by VLBI and GPS w.r.t. the official C04-series and the IERS2000 sub-daily model are shown in Figure 1. In spite of the big drift in the GPS estimates the combined UT1-UTC is aligned to the VLBI estimates. The RMS of the remaining differences to C04/IERS2000 can even be reduced from 0.015 ms for the VLBI-only solution to

0.011 ms for the combined solution, clearly demonstrating the advantage of an inter-technique combination. This improvement of the RMS due to an inter-technique combination can be seen for the x- and y-pole components as well, summarized in Table 3.

Table 3. RMS values of the remaining differences to C04/IERS2000 (offset removed).

	GPS	VLBI	Combination
X-pole [mas]	0.143	0.259	0.120
Y-pole [mas]	0.144	0.253	0.130
UT1-UTC [ms]	-	0.015	0.011

The capability of VLBI to determine UT1-UTC and the nutation offsets is sustained in the combination and is not disturbed by the satellite techniques as people are often worried about. The reason must be seen in the a posteriori formal errors of the estimated parameters that are displayed in Figures 2a and 2b for UT1-UTC and the nutation in obliquity, respectively. Whereas the VLBI estimates are more or less of equal accuracy during the entire time span, the UT1-UTC and nutation estimates from the satellite techniques heavily degrade with time. Daily values for UT1-UTC were generated for these two figures in order to show reasonable SLR results as well. Comparing GPS and VLBI only, the same behavior is visible for the hourly estimates.

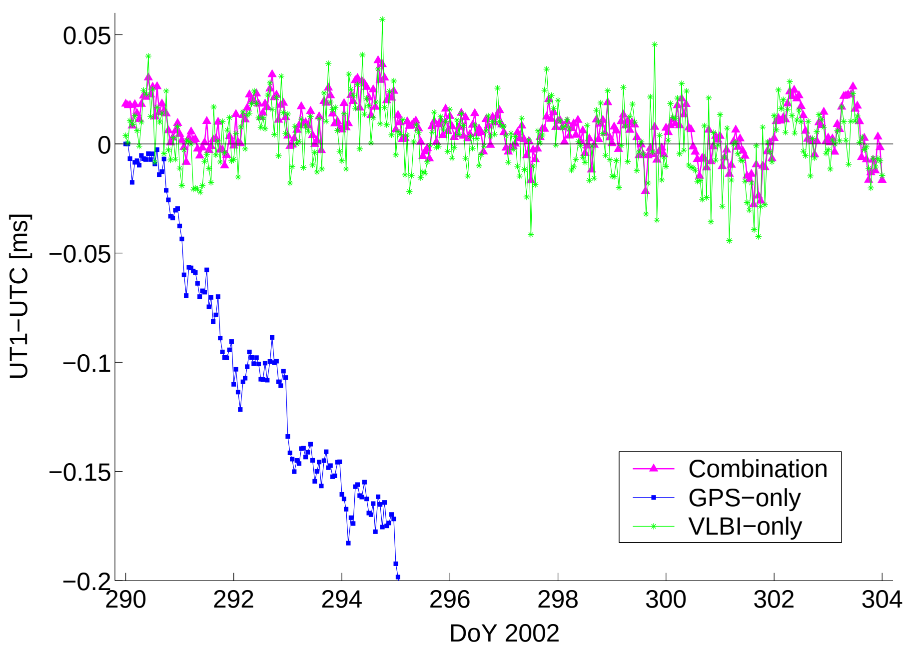


Figure 1. Hourly UT1-UTC estimates w.r.t. C04/IERS2000 derived from VLBI, GPS and a combined solution.

Analyzing the station coordinates gives an impression of the quality of the network. As far as the VLBI network of CONT02 is concerned, the distribution of the eight stations is obviously not perfect, especially in north-south direction. This imbalance between northern and southern

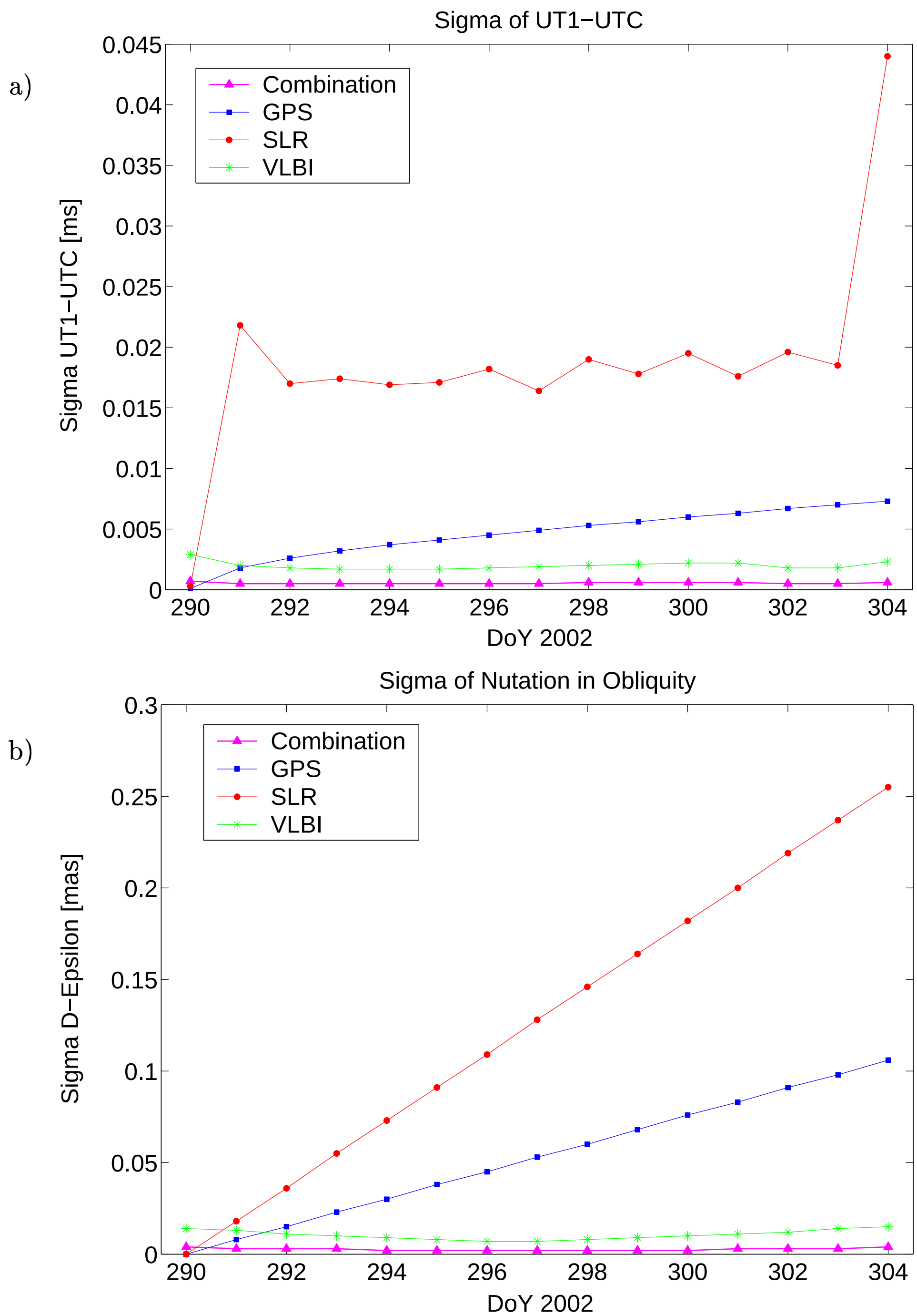


Figure 2. Formal errors of daily EOP estimates: (a) UT1-UTC, (b) Nutation in obliquity

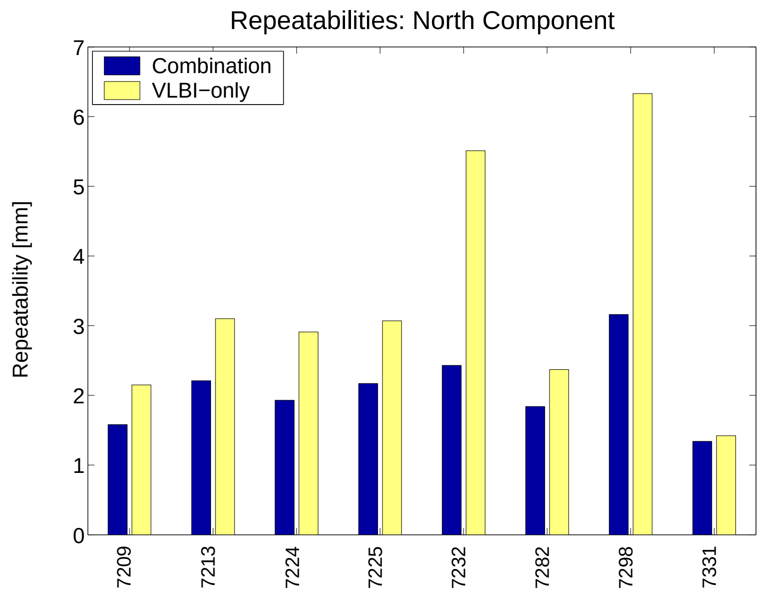


Figure 3. Repeatability of VLBI station coordinates before and after the combination with GPS (north component only).

hemisphere is reflected in the repeatability of the station coordinates. The mean repeatability for a VLBI-only solution is: 3.71 mm (north), 1.97 mm (east), 7.66 mm (height). In comparison, the mean repeatability for the more homogeneous GPS network of 150 stations is: 1.97 mm (north), 1.95 mm (east), 5.93 mm (height). This deficiency of the VLBI network can be compensated by the combination with GPS, where the datum definition is realized by a no-net-rotation condition for a subset of about 90 good and stable GPS stations and where the VLBI network is integrated through the eight local ties. Figure 3 shows the repeatability of the north component for the eight VLBI stations for a VLBI-only solution and for a combination with GPS. The improvement is clearly visible. However, an improvement of the RMS values due to the combination is not only achieved for the north component of the VLBI stations. Most of the station coordinates of both techniques improve in a combination, although this improvement is less pronounced (see Krügel et al. 2004).

It is widely known that the third parameter group, i.e., the tropospheric parameters (ZD and horizontal gradients), are highly correlated with the station coordinates. First of all, it must be stated that, in general, the agreement between the two techniques is very good. Let us start with looking at the tropospheric zenith delays. The height differences between the corresponding GPS and VLBI reference points have to be corrected for, if the ZD estimates of both techniques are to be compared or combined. For the studies presented here, the Saastamoinen model with mean surface meteorological data was used for this purpose. The modeled ZD differences to be expected theoretically (Saastamoinen) are compared to the differences between the space techniques averaged over 14 days (see Table 4). For Algonquin Park, Wettzell and Hartebeesthoek the agreement between the estimation and the model is quite good. The biases for Onsala, Fairbanks and Ny-Alesund might be caused by unmodeled phase center variations of the radomes installed on the GPS antennas, whereas the biases for Kokee Park and Westford cannot be explained at the moment. Although the errors in the zenith delay estimates due to a radome seem to be systematic, a conclusive statement about this topic cannot be given because the number of eight stations is too small and not enough studies were done up to now.

Table 4. Comparison of tropospheric zenith delay differences from the Saastamoinen model and the space techniques [mm].

	Model	GPS-VLBI Δ ZD	Diff. Δ ZD - Model	Radome
Ny-Alesund	0.96	-0.50	-1.46	yes
Onsala	4.53	1.17	-3.36	yes
Wettzell	0.98	1.26	0.28	
Hartebeesthoek	0.46	-0.40	-0.86	
Algonquin Park	7.33	7.28	-0.05	
Fairbanks	3.90	0.74	-3.16	yes
Kokee Park	3.04	8.40	5.36	
Westford	0.57	4.38	3.81	

The high correlation between tropospheric parameters and station coordinates can nicely be shown by means of the horizontal gradient estimates. In general, the gradients estimated independently by VLBI and GPS match quite well as shown in Figure 4a for the north gradient of the station Fairbanks. In a first step, all available local ties are introduced into the combination, whereupon the resulting gradients for VLBI and GPS (gradients not yet combined) show a clear bias (Figure 4b). As can be seen in Figure 4c, this bias can be removed if the north component of the Fairbanks local tie is not introduced into the combination. Together with comparably large discrepancies between the coordinate differences and the local tie values, this investigation leads to the conclusion that the north component of the local tie for Fairbanks should be disregarded in a combination. A very similar effect is present in the Westford local tie (east component).

Comparable studies were also performed for the correlation between the height component of the local ties and the tropospheric zenith delay differences between VLBI and GPS. Apparently, the height differences measured by the space techniques do not always agree with the local tie values available. If these "wrong" height differences are fixed in a combination by introducing the local ties, the discrepancies are absorbed by the tropospheric ZD because of the high correlation. This means that the ZD estimates change significantly. In order to see whether such problems can be avoided, the potential of combining the tropospheric ZD instead of introducing the local ties in height was tested. On the basis of the repeatability of the station heights, Figure 5 demonstrates that this alternative combination method works. Introducing only the horizontal local ties and combining the tropospheric ZD improves the repeatability in height compared to a solution without combining the ZD. However, as expected, the combination of the zenith delays cannot fully replace the direct combination of the height components.

For the validation of the tropospheric zenith delays independent measurements from water vapor radiometers (WVR) can be used. However, such measurements are not available for all CONT02 stations. As an example, the wet tropospheric zenith delay (ZWD) from the WVR and from a combined GPS/VLBI-solution (after removing the dry delay using pressure measurements) is displayed in Figure 6 for the station Wettzell. In view of the large offset (about 20.6 mm) and

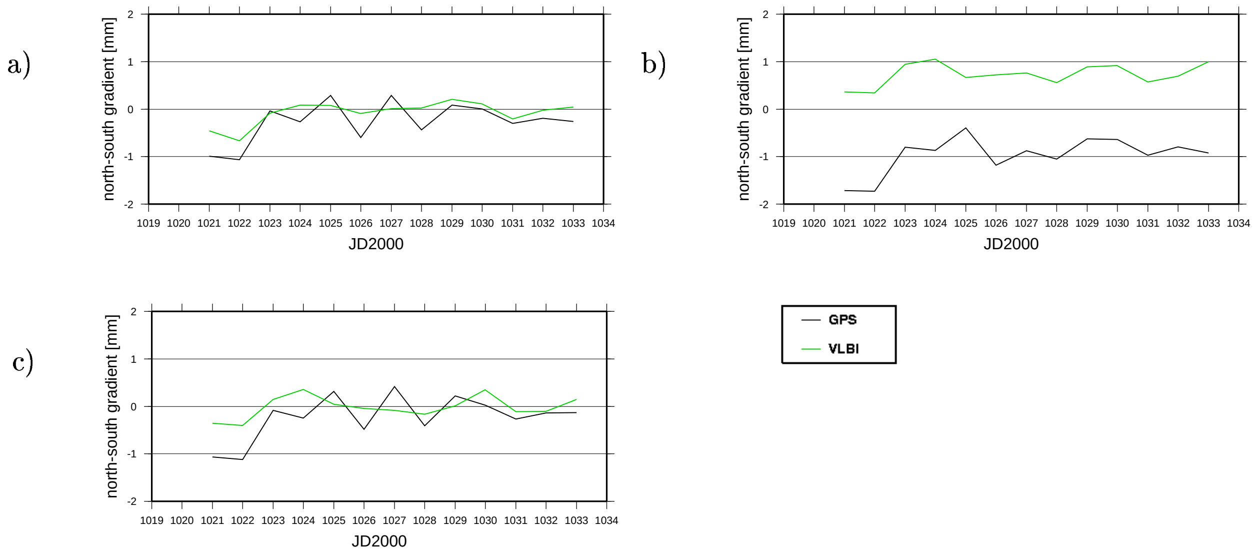


Figure 4. North gradient of Fairbanks from VLBI and GPS: (a) single technique solutions, (b) combination with all local ties, (c) combination with all local ties except for Fairbanks.

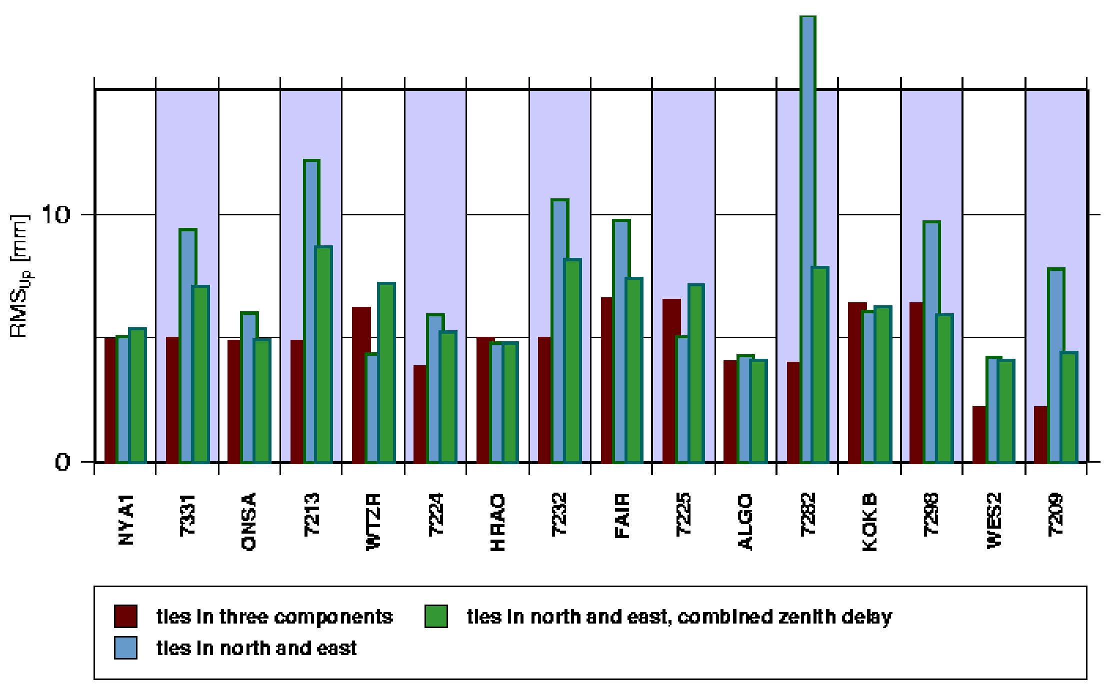


Figure 5. Repeatability of station heights for different combinations (shaded background for VLBI stations).

the high variability of the difference between the two techniques (14.5 mm), the usefulness of WVR for validating the tropospheric zenith delays of the space techniques is limited. In comparison, the RMS of the differences between GPS and VLBI zenith delay estimates is only about 6.9 mm, which means that these results are more stable by a factor of two. We have to add that analyses of the WVR data at Onsala were performed, yielding more encouraging companion results (see Elgered & Haas 2003).

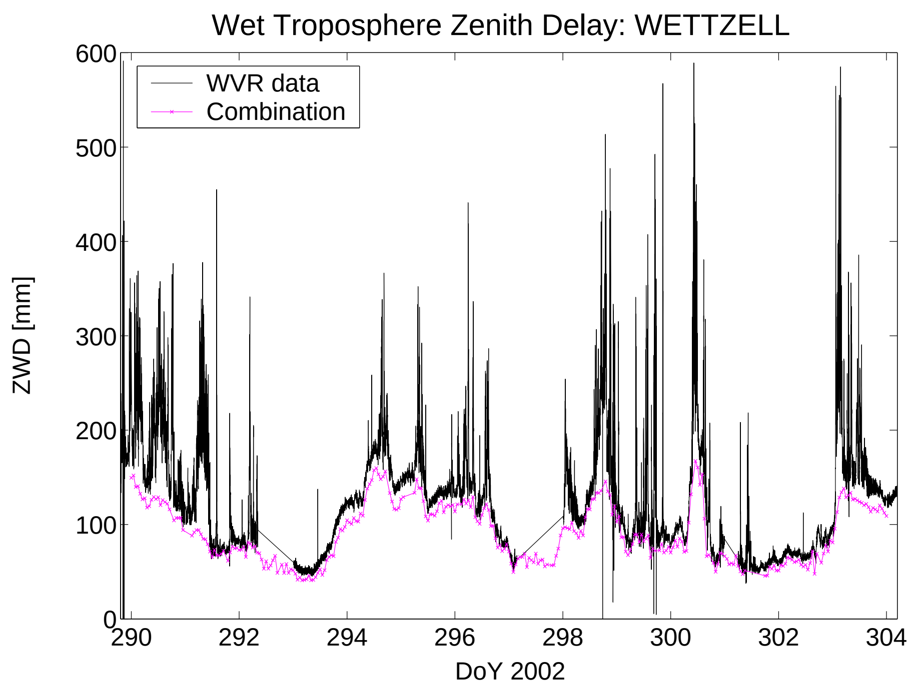


Figure 6. Comparison of wet zenith delays (ZWD) from space techniques and WVR at Wettzell.

4. Conclusions

The data of the continuous VLBI campaign CONT02, together with the data of the global GPS and SLR networks, has proved to be an excellent and unique data set to test rigorous combination algorithms and strategies. The combination of the CONT02 VLBI and GPS data has led to promising results for all parameters common to both techniques considered here, i.e., station positions, tropospheric parameters and Earth orientation parameters. As an important result, it could be demonstrated that the systematic effects present in LOD and nutation rates derived from satellite techniques do not necessarily result in a deterioration of UT1-UTC estimates and nutation offsets contributed to an inter-technique combination by VLBI. It was shown that tropospheric parameters are useful to detect problems in the local ties due to their strong correlation with station coordinates. When troposphere parameters are pre-eliminated before a combination, important inconsistencies between the techniques may hide in these parameters and go undetected. The analyses also showed that the combined solution can be improved by combining the tropospheric parameters. However, the remaining offsets in the tropospheric parameters for some of the stations still have to be analyzed in more detail.

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IVS Coordination

Coordinating Center Report

Nancy R. Vandenberg, Dirk Behrend

Abstract

This report summarizes the activities of the IVS Coordinating Center during the year 2004, and forecasts activities planned for the year 2005.

1. Coordinating Center Operation

The IVS Coordinating Center is based at Goddard Space Flight Center and is operated by NEOS (National Earth Orientation Service), a joint effort for VLBI by the U.S. Naval Observatory and NASA Goddard Space Flight Center.

The mission of the Coordinating Center is to provide communications and information for the IVS community and the greater scientific community and to coordinate the day-to-day and long-term activities of IVS.

The web server for the Coordinating Center is provided by Goddard. The address is

`http://ivscc.gsfc.nasa.gov`

2. Activities During 2004

During the period from January through December 2004, the Coordinating Center supported the following IVS activities:

- Directing Board support: Coordinated, with local committees, two IVS Directing Board meetings, in Ottawa, Canada (February 2004) and Makuhari, Japan (October 2004). Notes from each meeting were published on the IVS web site.
- Communications support: Coordinated the team that worked on the re-design of the IVS web site. Maintained e-mail lists and web-based mail archive files.
- Publications: Published the 2003 Annual Report in spring 2004. Published three editions of the IVS Newsletter in April, August, and December, 2004. Published the Proceedings of the third IVS General Meeting in summer 2004. All publications are available electronically as well as in print form.
- 2004 Master Schedule: Generated and maintained the master observing schedule for 2004. Coordinated VLBI resources for observing time, correlator usage, tapes and disk modules. Coordinated the usage of Mark 5 systems at IVS stations and efficient deployment of disk modules.
- 2005 Master Schedule: Generated the proposed master schedule for 2005 and received approval from the Observing Program Committee.
- Meetings: Coordinated, with the NRCan Local Committee, the third IVS General Meeting, held in Ottawa, Canada in February 2004. Chaired the Program Committee for the meeting.
- Observing Program Committee (OPC): Coordinated meetings of the OPC to monitor the observing program, review problems and issues, and discuss changes.

3. Web Site Re-design

The re-design of the IVS web site, which was started in 2003, was accomplished in late spring 2004 and the new site was installed in June. Maintenance of the new site was continued.

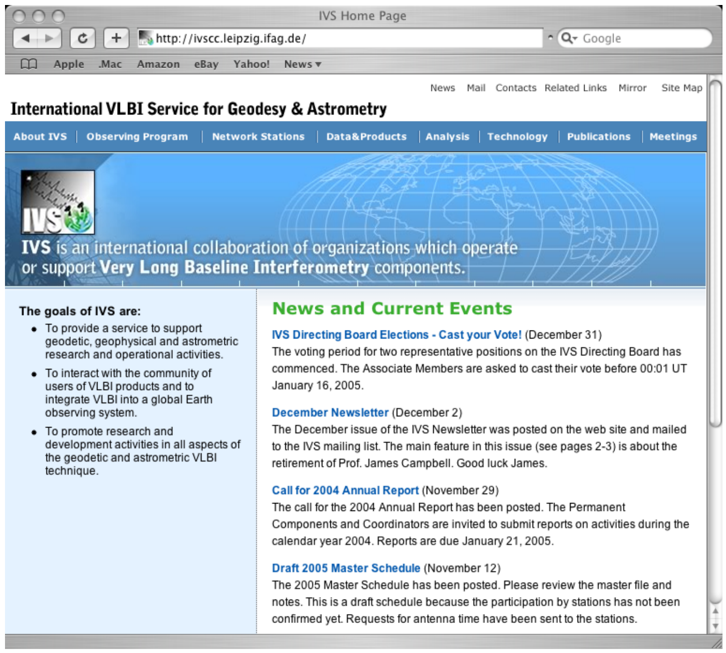

Figure 1. **IVS home page.** This screen shot (from Safari web browser) shows the new IVS home page at the BKG mirror site in Leipzig. The page displays the IVS logo, mission statement, goals, and current news and events. Navigation is accomplished with the section links “About IVS”, “Observing Program”, and so on which appear on every page. Other useful links such as “News” and “Mail” are compiled in a secondary navigation bar in the upper right.

The web site covers three main topics for IVS: activities, organization, and products. The site works to serve three main purposes:

- To provide a location on the web for IVS members and members of the scientific community to find data, products and general information provided by IVS.
- To act as a hub of information for IVS members. Since participants in the program are spread all over the world, the web site can act as a good resource to keep members informed of IVS activities.
- To promote IVS and to educate the scientific community and other interested parties in the work IVS is doing.

The new site offers much improved navigation, updated content, and a logical structure. The IVS Web Team was led by Nancy Vandenberg (NVI/GSFC) and included Hayo Hase (BKG), Yasuhiro Koyama (NICT), Zinovy Malkin (IAA), Dan Smythe (Haystack), Christoph Steinforth (GIUB). The site design and initial site construction were done by web designer Doug League of the Technical Information Services Branch at NASA's Goddard Space Flight Center. The site's home page is http://ivscc.gsfc.nasa.gov/. Mirror addresses are http://ivscc.leipzig.ifag.de/ at BKG in Germany and http://ivs.nict.go.jp/mirror/ at NICT in Japan.

4. Staff

The staff of the Coordinating Center is drawn from individuals who work at Goddard. The staff and their responsibilities are:

Name	Title	Responsibilities	Allocation
Nancy Vandenberg	Director	Web site overview, Directing Board support, meetings, publications	50%
Dirk Behrend	Deputy Director	Web site maintenance, e-mail system maintenance, meetings coordination, publications	50%
Cynthia Thomas	Operation Manager	Master schedule (current year), resource management, meetings and travel support, special sessions	50%
Frank Gomez	Web Manager	Web server administration, mail system maintenance, data center support, session processing scripts, mirror site liaison	50%
Karen Baver	Publication Programmer and Editor	Publication processing programs, Latex support and editorial assistance	10%
Debra Gonzalez	Data Technician	Master schedules, resource monitoring, session web pages monitoring	30%

5. Plans for 2005

The Coordinating Center plans for 2005 include the following:

- Support the new IVS web site and implement new station pages.
- Publish the 2004 Annual Report (this volume).
- Coordinate the Technical Operations Workshop (TOW), to be held at Haystack Observatory.
- Coordinate, with the local committee, the fourth IVS General Meeting, to be held in Concepcion, Chile, in February 2006.
- Support Directing Board meetings in 2005.
- Coordinate Directing Board elections.
- Coordinate the 2005 master observing schedule and IVS resources.
- Publish Newsletter issues in April, August, and December.
- Publish an IVS color brochure.

Analysis Coordinator Report

A. Nothnagel, C. Steinforth

Abstract

IVS analysis coordination issues in 2004 are reported here.

1. General Issues

The "Fifth IVS Analysis Workshop" was held at Lord Elgin Hotel in Ottawa, Canada, February 12, 2004. Detailed information on the presentations and discussions can be found in [2].

As of January 1, 2005, Mrs. Dorothee Fischer (dorothee.fischer@uni-bonn.de) will take over responsibility for the EOP combination activities at the IVS Analysis Coordinator's office. Unfortunately, Christoph Steinforth has to leave us due to German university regulations. He has done a very good job for the IVS since the very beginning of IVS EOP dissemination. For his new position we wish him the same success and fun as he had at our institute.

2. IVS Operational Data Analysis and Combination

2.1. Terrestrial Reference Frame

The year 2004 marked a considerable step forward in the maintenance of the terrestrial reference frame (TRF) from geodetic VLBI observations. For the first time not only groups using the Calc/Solve program were able to generate a TRF solution from almost all high precision geodetic VLBI observations. Now, TRF solutions can also be computed by the *Deutsches Geodätisches Forschungsinstitut* (DGFI) in Munich, Germany, using the OCCAM VLBI software together with a DGFI combination program called DOGS-CS. Another TRF realization has been computed by the *Main Astronomical Observatory* (MAO), Kiev, Ukraine, with the software package SteelBreeze.

First steps have been taken for a combination of a series of four TRF realizations (two from Calc/Solve, one from OCCAM and one from SteelBreeze) on the basis of coordinates, velocities and their formal errors. In order to map the results onto a common datum, the same procedures have been applied as described in [1]. After small global rotations and translations of only a few millimeters and a few μas, the solutions agree very well. In particular, the individual scales of the TRF realizations are very consistent indicating that the models of the three independent software packages agree rather well.

Only in rare cases the agreement in the station coordinates at a common reference epoch was not satisfactory. One of the reasons is that different data spans have been used for the computations leading to incomplete data sets for a few stations which observed only in the early 1980's. The other reason for unacceptable differences surfaced only after extensive investigations: Differences in the values for the antenna axis offsets (see 2.2).

The different lists of antenna axis offsets in use at the IVS Analysis Centers motivated the IVS Analysis Coordinator to compile and issue an official list of antenna axis offsets which is recommended for use by all IVS Analysis Centers. Currently, re-computations of TRF realizations using the recommended axis offsets are underway.

2.2. Antenna Axis Offsets

Only in very few cases do the two main axes of a radio telescope really intersect. Mostly, the distance between the two axes, called the VLBI antenna axis offset, is in the range of a few millimeters, mainly for azimuth-elevation mounts (see Figure 1), up to several meters, mainly for hour-angle-declination or X-Y mounts. The knowledge of the exact axis offset is of extreme importance. Each VLBI delay observation has to be corrected for the axis offset effect and any error in this directly affects the vertical component of a station's position.

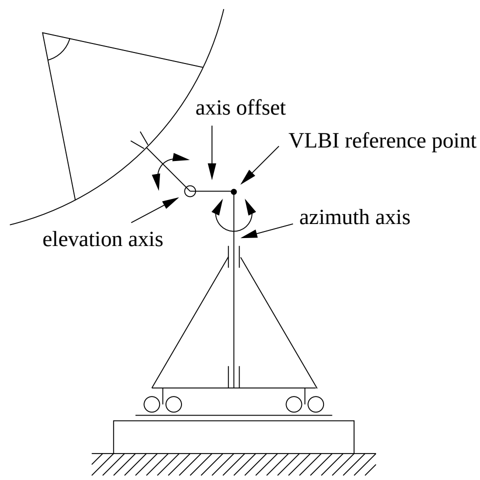

Figure 1. Axis offset of an azimuth-elevation mount (Courtesy R. Haas)

At the beginning of precision geodesy with VLBI the axis offsets have been taken from antenna construction drawings while later axis offsets were also estimated as global parameters from VLBI observations. In the meantime, the axis offsets of a very small number of telescopes have been measured locally with very high accuracy. A few of the results fit the estimates reasonably well but some of them don't at the level of up to 5 mm. Even more important is the fact that the measurements often do not match the values in the drawings. The reason for the discrepancies between measurements and estimates may be that the latter comprise any other residual effect which may have a cosine(elevation) signature.

The consequences of all this are twofold: On the one hand there is an enormous potential for improving the TRF results from VLBI observations. On the other hand earth orientation parameters (EOP) as determined by IVS Analysis Centers using different lists of axis offsets suffer from inherent systematic differences. The latter has not been very obvious and has, thus, not been considered yet.

Currently, all axis offsets measured or estimated reliably are being compiled for consistent use by all IVS Analysis Centers. For more details see the IVS Analysis Coordinator's web page (http://giub.geod.uni-bonn.de/vlbi/IVS-AC).

Compared to the general effort of VLBI observations, processing and analysis, the determination of the axis offsets does require relatively little work using standard surveying equipment and procedures. We strongly encourage the observatories with unreliable axis offset information to carry out the necessary measurements. Please contact the author if you need further advice.

2.3. IVS EOP Series

In 2004, six IVS Analysis Centers have again contributed routinely to the IVS Combined EOP series. However, in this year the Main Astronomical Observatory Kiev, Ukraine, has replaced the analysis center of St. Petersburg University, now adding the contribution of a third software package, SteelBreeze. This third software package, which has been developed completely independently, helps to make the combination products even more robust and broadens the basis for investigations of systematic effects.

In the course of the year the combination of the EOP series has been further refined through implementation of correlation information between analysis centers. Since all analysis centers use the same raw observation data for the computation of the EOP series, the input series cannot be considered independent. However, through quite a number of different reduction steps for the correction of the observables and the determination of the theoreticals, the O-C value for each observation is rather different for any of the analysis centers. The correlation coefficients are, thus, reduced quite a bit but are significant nevertheless. For more details see [3].

3. Combination of VLBI Sessions for the IERS Combination Pilot Project

In 2004 the IERS has issued a call to the IAG services/IERS Technique Centers to contribute input to the IERS Combination Pilot Project. The official input of IVS consists of SINEX files which are combined solutions of several IVS Analysis Centers. Each SINEX file contains a datum-free normal equation for a single session. Parameters are station coordinates and earth orientation parameters plus their time derivatives. In the course of the year, the first combined SINEX files have been compiled. At the beginning only SINEX submissions from the Calc/Solve software package (GSFC, USNO, BKG) were available. Now, also DGFI regularly submits SINEX files while MAO is preparing to do so after the procedure is set up properly.

The normal equations of these SINEX files are being scaled, added and resent to the IVS Data Centers and to the IERS CPP data base. So far about 70 VLBI sessions have been combined. Some feedback from the IERS Combination Centers shows the importance of IVS' contribution to this project. Furthermore, since the ITRF2004 will be computed by means of combination of normal equations this work is the only way for the IVS to contribute to the new terrestrial reference frame.

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Network Coordinator Report

Ed Himwich

Abstract

This report includes an assessment of the network performance in terms of the yield of usable data over a 12 month period. Overall, the data loss for 2004 was about 12.5%. A table of relative incidence of problems with various subsystems is presented. The most significant causes of data loss were antenna reliability (accounting for about 33%), receiver problems (18%), recorder problems (11%), and RFI (5-10%). The current situation for the handling of correlator clock adjustments by the correlators is reviewed. The adjustments are not currently handled in a consistent way and this has an impact on the UT1-UTC estimates from VLBI data. Some work will be required to correct this problem.

1. Network Performance

The network performance report is based on correlator reports for sessions in calendar year 2004. This report is based on 153 sessions that have been processed. There are nine sessions that were processed by the VLBA, but those results were left out of this analysis since the filed reports tend to be less detailed than those from other correlators. There are another 29 sessions from the calendar year that had not been processed or the correlator results were not available. Most of these missing sessions are being processed by the Penticton correlator, are waiting for tapes from Antarctica, or are from the latter part of the year. Roughly 80% of the scheduled station days for 2004 are accounted for.

An important point to understand is that in this report the data loss is expressed in terms of lost observing time. This is straightforward in cases where the loss occurred because operations were interrupted or missed. However, in other cases, it is more complicated to calculate. To handle this a non-observing time loss is typically converted into an equivalent lost observing time by expressing it as an approximate equivalent number of recorded bits lost. As an example, a warm receiver will greatly reduce the sensitivity of a telescope. The resulting performance will be in some sense equivalent to the station having a cold receiver but observing for (typically) only one-third of the nominal time and therefore only recording one-third of the expected bits. In a similar fashion, poor pointing is converted into an equivalent lost sensitivity. Poor recordings are simply expressed as the fraction of total recorded bits lost.

Using correlator reports, an attempt was made to determine how much observing time was lost at each station. This was not always straightforward to do. Sometimes the correlator notes do not indicate that a station had a particular problem while the quality code summary will indicate a significant loss. Reconstructing which station or stations had problems and why in these circumstances does not always yield accurate results. Another problem was that it is hard to determine how much RFI affected the data unless one or more channels were removed and that eliminated the problem. Similar problems occur for intermittent poor playback. For individual station days, the results should probably not be assumed to be accurate at better than the 5% level.

The results here should not be viewed as an absolute evaluation for the quality of each station's performance. As mentioned above the results themselves are only approximate. In addition, some problems are beyond the control of the station, such as weather and power failures. Instead the results should be viewed in aggregate as an overall evaluation of how much of the data the network is collecting as a whole. Development of the overall result is organized around individual station performance, but the results for individual stations do not necessarily reflect the quality of operations at that station.

Since stations typically observe with more than one other station at a time, the lost observing time per station is not equal to the overall loss of VLBI data. Under some simplifying assumptions, the loss of VLBI data is roughly about twice the loss of observing time. The argument that supports this has been described in the Network Coordinator's section of the 2002 Annual Report.

For the 153 sessions from 2004 examined here, there are 966 station days or slightly more than 6 stations per session on average. Of these session days about 12.5% (or about 120 days) of the observing time was lost. For comparison to earlier years, see Table 1.

Table 1. Lost Observing Time

Year	**Percentage of Days Lost**
1999-2000*	11.8
2001	11.6
2002	12.2
2003	14.4
2004	12.5

* The percentage applies to a subset of the 1999-2000 sessions.

The lost observing time for 2004 was down slightly from 2003. It has returned to levels more typical of previous years, around 12%. If these observing time losses are converted into VLBI data yield losses, then 2004 had about 25% VLBI data loss and 2003 about 29%. Whether these results reflect an actual improvement in performance is not clear (e.g., there are some questions about Gilcreek's clock performance that are discussed below). It is however reassuring that the performance has returned to levels typically seen in previous years. This is in spite of significant problems with telescopes and receivers in 2004.

An assessment of each station's performance is not provided in this report. While this was done in some previous years, this practice seems to be counter-productive. Although many caveats were provided to discourage people from assigning too much significance to the results, there was feedback that suggested that the results were being over-interpreted. Some stations reported that their funding could be placed in jeopardy if their performance appeared bad even if it was for reasons beyond their control. Last and least, there seemed to be some interest in attempting to "game" the system to improve the individual results. Consequently, only summary results are presented.

For the purposes of this report, the stations were divided into two categories: (A) those that were included in 20 or more network sessions, and (B) those in 13 or fewer. Some of the stations in the former category had been included in more than 70 sessions. The distinction between these two groups was made on the assumption that the results would be more meaningful for the stations with more sessions.

There are 15 stations in the 20 or more session category. Of these, nine successfully collected data for approximately 90% of their expected observing time. Five more stations collected 84% or more. One station in this group collected slightly less than 80%.

There are 22 stations in the 13 or fewer session category. The range of successful observing time for stations in this category was 0%-100%. The median success rate was 83%. Overall the stations in this category observed successfully about 94% of the 113 station days (12% of the total analyzed) that fall in this category..

Although the results are not being reported for individual stations, a few stations deserve special recognition for how much their data collection improved from the previous year. Four stations improved the percentage of data they collected by more than 5%. These stations are Svetloe, TIGO, Seshan, and Kokee. Given the high level of reliability of these stations it will be difficult for most of them to improve by this much again next year.

The losses were also analyzed by sub-system for each station. Individual stations can contact the network coordinator (weh@ivscc.gsfc.nasa.gov) for the break-down for their individual station. A summary of the losses by sub-system (category) for the entire network is presented in Table 2.

Table 2. Data Lost by Sub-system

Sub-System	**Percentage lost**
Antenna	32.9
Receiver	18.0
Recorder	11.1
Unknown	10.1
Miscellaneous	8.0
Rack	6.8
Operations	6.1
RFI	5.0
Shipping	1.4
Clock	0.5
Software	0.1
Total	100.0

The categories in Table 2 are rather broad and require some explanation. The "Antenna" category includes all antenna problems including mis-pointing, antenna control computer failures, and mechanical break-downs of the antenna. The "Receiver" category includes all problems related to the receiver including out-right failure, loss of sensitivity because the cryogenics failed, and design problems that impact the sensitivity. The "Recorder" category includes all electrical and mechanical problems related to the recorder system (tape or disk). This includes passes that are unrecoverable because of overwriting. The "Unknown" category is a special category for cases where the correlator did not state or was unable to determine a cause of the loss, but also includes the upper X-band IF problem at TIGO which has yet to be understood. In addition, some reports of low fringe amplitude in various channels were included in this category although some of them perhaps should have been included in "RFI". The "Miscellaneous" category includes several small problems that do not fit into other categories, including errors in the observing schedule provided by the Operation Centers. Power failures are also included in this category. The "Rack" category includes all failures that could be attributed to the rack (DAS) including the formatter and BBCs.

The “Operations” category includes all operation errors, such as DRUDG-ing the wrong schedule, starting late because of shift problems, problems changing tapes and others. The “RFI” category includes all losses directly attributable to interference. The “Shipping” category includes data that could not be correlated because the media was either lost in shipping or held up in customs long enough that it could not correlated with the rest of the session data. The “Clock” category includes situations where correlation was impossible because either the clock offset was not provided or was wrong leading to no fringes. It is difficult to be sure in some of these cases that the clock offset was the culprit, but in some it was clear. In cases where it was not, the loss was assigned to the “Unknown” category. The “Software” category includes all instances of software problems causing data to be lost. This includes crashes of the Field System, crashes of the local station software, and errors in files generated by DRUDG.

From the results it can be seen that antenna and receiver together account for more than 50% of the losses, which is an increase of almost 10% above last year. In fact for 2004 there were several unusual receiver and antenna problems. In particular, Kokee, Wettzell, and Gilcreek had antenna problems that contributed to nearly 50% or more of each station’s lost data. Some of these problems are continuing. Kokee’s operation continues to be hampered while one of its azimuth gear boxes is repaired. The remaining gear box will also require maintenance soon. Wettzell has recently upgraded its control system, which accounts for much of its down time. Gilcreek has both mechanical and control system problems. This antenna is about 40 years old and the control system about 30 years old. These results also discount the continuing inability of Matera to observe because of a problem with the antenna rail. For the first part of the year, Matera was still included hopefully in the scheduling process, but after about two months no further attempts were made to schedule the antenna. If it had been, it would have contributed about another 60 lost days. This would have increased the overall days lost by the network to about 17.6% with about 55% being due to antenna problems alone. However, this is an unduly pessimistic estimate since other stations were substituted for Matera for almost two-thirds of the sessions they would have missed.

Stations with significant receiver problems include Fortaleza, Westford, HartRAO, Ny-Ålesund and Seshan. Most of these problems are in the category of reliability problems with the cyrogenics, power supplies or amplifiers, but for Seshan the most significant issue is the roll-off in the X-band bandpass, which has been included in this category.

The other most significant problem areas were Recorder, Miscellaneous, “Unknown” and RFI. Of these Recorder is by a small amount the most substantial. Most of items in this category are tape related. However, a small fraction represent problems with Mark 5 and other disk type recording systems. It is expected that Recorder issues will become less significant as more stations start using disk systems and the initial problems with these systems are resolved. However for now the results are no better than last year’s recorder loss of 10.9%. The RFI category represents about a 5% loss. However, the actual number may be higher because some problems that were classified as either Receiver or “Unknown” due to lack of information might be more correctly attributed to RFI. It may be that the RFI losses should be as large of 10%, which is more in line with the previous year’s result of 9.3%. The loss of TIGO due to the upper X-band IF problem represent about half of the overall network “Unknown” losses and above half of TIGO’s losses as a station. No discussion of the items in the Miscellaneous category beyond the general description of these categories above is needed

A significant item that gets some attention in the correlator reports is that Gilcreek’s Maser developed significant problems in the last third of the year. The problem has been difficult to troubleshoot and as of the writing of this report, was still not fully understood. The symptoms were that delay jumps of 100-300 picoseconds were being observed by the correlators and the data analysts were reporting significantly noisier than usual, by factors of several, clock variations. The noise level was bad enough that Gilcreek VLBI data were only marginally useful in the sessions where this problem occurred. In the process of trouble-shooting, it was noticed that the analysis results using Rubidium frequency standard were no worse and maybe slightly better than those using the Maser, so operations were switched the Rubidium in early 2005. This sort of problem is difficult to represent in the analysis of this report since it doesn't actually cause a loss of data, even due to a loss of coherence. However, we can to some extent work backward from the impact on the sigmas of the station's coordinates in geodetic solutions. This is difficult to accurately gauge because of differences in sessions, but it is plausible that this has roughly doubled the Gilcreek coordinate sigmas for the affected sessions. The equivalent observing time loss is about 75%. This would correspond to an additional loss of about 22 observing days for the 30 or so experiments where Gilcreek observed with this problem. This issue would probably be categorized as a "clock" problem although in the past this category has only been used for problems with the offsets. Using this analysis the overall percentage of lost days for the network would have increased to about 14.8%. The percentage of the loss due to clock problems would be about 15.8%. It should be noted however that this is a very unique problem. It has hardly ever, if not never, occurred before in the history of geodetic VLBI. We can have some hope that it is unlikely to recur.

2. Clock Offsets

As noted in the Network Coordinator's report for last year, it is important to develop consistent procedures for handling the clock offsets during the correlation process. Stations measure the offset between their formatter and the UTC time provided by GPS. The correlators typically apply a small, few μseconds or less, adjustment to the measured offsets in order to align the data to get fringes. If the adjustments are not applied in a consistent fashion by all correlators a corresponding error will be made in the UT1-UTC parameter adjustments. This will affect the quality of IVS UT1-UTC products at the level of the inconsistency in the adjustments applied for correlation. This could be corrected during the data analysis, but currently no analysis packages do this. It would require a significant amount of bookkeeping to add this feature now.

The Network Coordinator's report from two years ago recommended that the correlators develop a consistent table of adjustments to correct the local measurements of the formatter relative to GPS. This would remove a source of correlator-to-correlator and session-to-session variability in the UT1-UTC results. It was suggested that in developing this table the applied correction for Kokee should be artificially set to zero. Although not strictly correct, it is a simple approach and will maintain a level of consistency with old data, much of which was processed by WACO with an offset of zero for Kokee. However, the "true" adjustment will have to compensated for when an effort is made to align the ICRF and ITRF at this level. It was also recommended in the report from two years ago that a reference for the clock rate should be established at the same time. Although this is not as critical as the offset, it can easily be handled at the same time. Of course a good candidate station for the clock rate reference has to be found. As of the report two years ago, it seemed that Kokee's small rate relative to GPS, 1e-14 or better, would make it a good candidate. This would be a convenient choice for consistency's sake since again WACO has assumed that Kokee had a zero rate for much of the old data. This discussion is carried on in more detail in the report from two years ago.

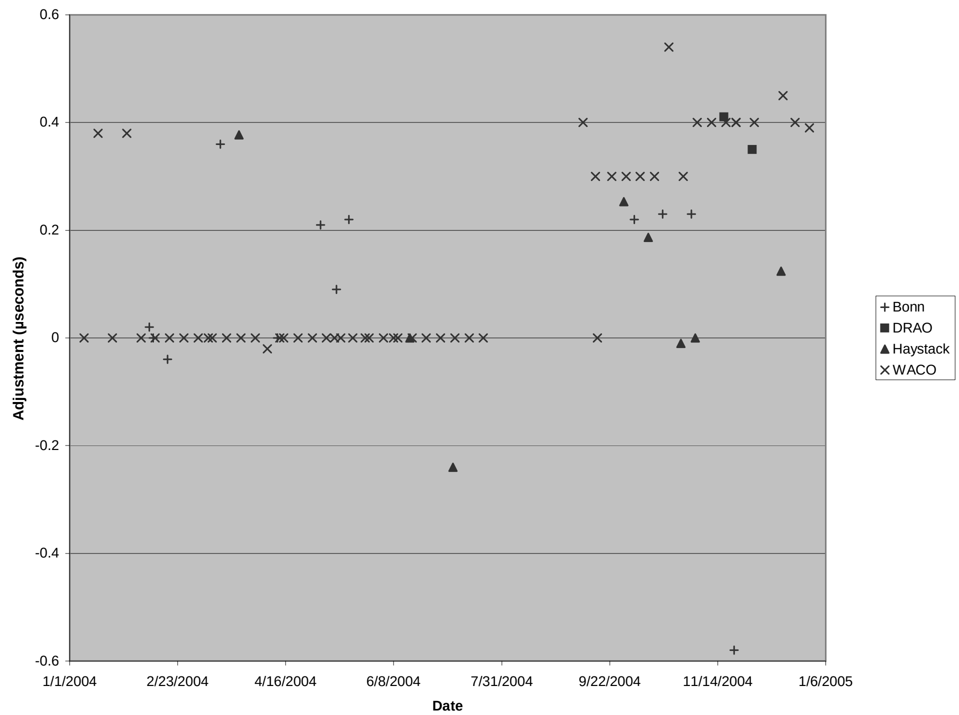

Figure 1. **Kokee UTC Correlator Adjustment**

Some progress has been made in implementing this recommendation, but this effort has not been completed. At the IVS Directing Board meeting in September 2003, the Correlator Representative to the Directing Board had offered to develop a consistent set of adjustments for the correlators to use. Currently this set of adjustments is under development [K. Kingham, USNO, private communication]. Consequently it would be premature to expect the offsets to be consistent for 2004. As a sample of the situation in 2004, the adjustments for Kokee are shown by correlator in Figure 1. In this figure it can be seen that the UTC offsets applied by WACO are small and in some cases zero. The non-zero values are probably related to use of Mark IV formatter which has an intrinsic offset of about 0.4 μseconds relative to the VLBA formatter that was also in use at that station. This is an example of equipment dependent offsets. WACO appears to have compensated appropriately for this case. Both Bonn and Haystack used variable but small non-zero adjustments. The variations however seem unrelated to the equipment in use. In the case of the large offset for Bonn in November this probably introduced a nearly one μsecond offset in the UT1-UTC for this experiment relative to other nearby sessions. The offsets applied by Penticton (DRAO) appear to be more consistent with the other correlators than had been the case in previous years. However, we have no information about the relative offset of the S2 equipment used for the sessions that Penticton correlates relative to the equipment used for other sessions. In general, the results for UT1-UTC will be affected at the level that the adjustments vary, in this case less than about 0.5 μsecond.

It is not only important that the UTC adjustments applied by the correlators are all consistent, but also the final clock value must be applied in the generation of the time-tags for the observations. It is known that this is done at the three Haystack Observatory developed correlators: Bonn, Haystack, WACO, and Penticton (DRAO). However it is not known what the GSI correlator does in this regard. A request has been made to K. Takashima to find out more about how the GSI correlator handles the offsets. (We also have no information about clock offsets are handled by the Miytaka correlator. However, the IVS geodetic sessions that Miytaka process are not primarily intended to measure UT1-UTC.) If the final clock value is not applied in the generation of the time tags, the session-to-session variation in the locally measured formatter to GPS will be included in the UT1-UTC parameter estimates.

Another area of concern is that different recording systems may require different adjustments. The Mark IV to VLBA formatter offset difference mentioned previously is an example of this. A more extreme example is from the CRF22 session from 2003. It was correlated at WACO using data from two different systems: K3 formatter recorded to tape and a K5 recorder using disks. WACO found a 2.3 μsecond clock offset between the two systems. This difference corresponds to almost a kilometer of cable difference. This does not seem realistic. If no cause for this is found, and probably even if it is, it will necessary to calibrate the differences between different systems. This might be undertaken by recording the same data with two or more systems possibly in heterogeneous networks and then comparing the final clock offsets that are needed to correlate them. Measuring and using these system specific offsets is a necessary step in implementing consistent correlator clock offset handling.

IVS Technology Coordinator Report

Alan Whitney

Abstract

Abstract: The efforts of the Technology Coordinator in 2004 were primarily in the following areas: 1) continued work on IVS Working Group 3 "VLBI2010" study, 2) continued development and deployment of e-VLBI, 3) support of the 3rd annual e-VLBI Workshop held in Japan. We will describe each of these briefly.

1. IVS Working Group 3 - VLBI2010

Work continues towards the conclusion of the IVS Working Group 3 (WG3) "VLBI2010" report. A first draft report completed in the fall of 2004 is undergoing review and revision. VLBI2010 is examining current and future requirements for VLBI geodetic systems, including all components from antennas to analysis, and will produce a report with recommendations for a new generation of systems that meet the following criteria:

- Highest-precision geodetic and astrometric results
- Low cost of construction
- Low cost of operation
- Fast turnaround of final results

Among the issues being explored are:

- Modernization of VLBI data-acquisition systems for higher stability and reliability, wider bandwidth, lower cost
- Small, low-cost, fast-moving antennas
- New observing strategies
- Optimum and practical observing frequencies
- Fully automated observations; remote monitoring
- Transmission of data via high-speed network (e-VLBI)
- Possible correlator upgrades
- Fast turnaround of results by full pipelining of data from antennas to correlator to final analysis

Among the factors encouraging VLBI 2010 initiative:

- Continuing RFI problems at many sites
- DSN moving to X/Ka (32 GHz) band observations.
- Aging antennas
- Technology advances in disks and e-VLBI

- Concerns in the US:
  - Retirement of current practitioners
  - Reduced support for VLBI technology development by sponsoring agencies

We are drawing on the resources of both the astronomy and geodesy VLBI communities in these investigations, as well as other relevant expertise (such as SKA and ATA, for example).

The VLBI2010 Working Group is composed of 16 members drawn broadly from the geodetic VLBI community:

- Brian Corey–antennas, RF/IF systems, calibration
- Hayo Hase–antenna systems
- Ed Himwich–control, data management
- Hans Hinteregger–digital backend systems, correlators
- Tetsuro Kondo–data systems, data transport, real-time
- Yasuhiro Koyama–data systems, data transport
- Chopo Ma–post-correlation analysis; data management
- Zinovy Malkin–post-correlation analysis
- Arthur Niell–atmospheric calibration, analysis
- Bill Petrachenko–antenna arrays, multi-beam VLBI, frequency standards
- Wolfgang Schlüter–antennas, observing strategies, frequency standards
- Harald Schuh–post-correlation analysis, cross-technique use
- Dave Shaffer–observing strategies, systems, analysis
- Gino Tuccari–digital backend systems
- Nancy Vandenberg–scheduling, observing strategies
- Alan Whitney–data systems, data transport, correlators

The Working Group is co-chaired by Alan Whitney and Arthur Niell. A final report is expected to be available in spring 2005.

2. e-VLBI Development

e-VLBI development is continuing on a number of fronts, which we will briefly mention here.

2.1. VSI-E Reference Implementation

A reference implementation of the proposed VSI-E specification has been developed. This implementation is intended to act as a demonstration model for VSI-E and is available to all interested parties. The VSI-E framework provides signaling, control, framing and statistics support and is an extension to the Internet standard RFC3550. It also provides flexibility in that it allows users to choose the transport protocol that most suits their networking environment (e.g. UDP, TCP or other variants). Once the reference implementation is fully checked out, attention can be turned to optimizing the code for high-speed operation.

2.2. Continuing Expansion and Development of e-VLBI Experiments

e-VLBI continues to grow rapidly. Within the last year, e-VLBI transfers for geodetic-VLBI have become routine, particularly between Japan and the U.S. for data recorded at Kashima, and between Japan and Europe for monthly UT1 data recorded at Tsukuba. We expect that daily UT1 Intensives taken at Kokee and Wettzell will soon be transmitted regularly to the USNO correlator. Transfer rates, especially across international networks continue to improve. Japan/U.S. transfer rates as high as ~900 Mbps have been observed, with sustained rates as high as ~700 Mbps. Work is on-going between U.S. and Europe, and we expect soon to conduct a 512 Mbps real-time experiment between the U.S. and Europe. 512Mbps real-time experiments using the Mark 5A have already been conducted within the U.S.

The biggest impediment to rapid e-VLBI expansion continues to be station connectivity to high-speed networks, but that is improving. Tsukuba, Kashima, Onsala, and Westford are all, in principle, connected at 1 Gbps, though some issues remain in actually using some of the links at full speed. Wettzell and Kokee are connected at somewhat lower speeds. And there are indications that some other stations may soon be connected at good speeds and start to become usable for e-VLBI.

3. Third International e-VLBI Workshop Held at Makuhari, Japan

Approximately 70 attendees representing 13 countries participated in a 2-day workshop hosted by NICT and held in Makuhari, Japan on 6-7 October 2004. The purpose of this workshop was to continue the work of the 2002 and 2003 e-VLBI workshops held at Haystack Observatory and JIVE to explore the current state and future possibilities of high-speed VLBI data transmission. Among the topics discussed were:

- Reports on e-VLBI tests and demonstrations
- Plans for ongoing e-VLBI development
- Status of interaction with network providers and developers
- International networking facilities - now and future
- Standards and protocols for e-VLBI data transfer.
- Hardware and software interfaces to telescope back-ends and correlators

During the workshop, many exciting developments in the field of e-VLBI and high-speed networks were presented. Researchers from high-energy physics and education also participated since there are many common interests. Progress in e-VLBI continues to be rapid, particularly with the rapid spread of global high-speed networks, the adoption of e-VLBI compatible data systems (Mark 5, K5, PC-EVN), and the rapid drop in prices for high-speed network equipment. In addition to e-VLBI data transmission, we heard about the development of new software correlators in Japan, Europe and the U.S., as well as plans for continued e-VLBI development in many countries. An international e-VLBI technical committee was established, led by David Lapsley of Haystack Observatory. With the departure of David from Haystack in December 2004, we are looking to re-organize this committee with a new technical leader. The program committee consisted of Yasuhiro Koyama of NICT, Steve Parsley of JIVE, Jon Romney of NRAO and Alan Whitney of Haystack Observatory. Presentations from the workshop are available online at `http://www2.nict.go.jp/ka/radioastro/evlbi2004/`. We warmly thank MCT and our Japanese colleagues for hosting such a fine meeting, even providing the additional exciting attractions of an earthquake and a typhoon! Tasso Tzioumis of CSIRO proposed that the next e-VLBI workshop be held in Australia in July 2005. The proposal was warmly accepted and is being looked forward to by all.

Network Stations

Algonquin Radio Observatory

Mario Bérubé, Anthony Searle

Abstract

The Algonquin Radio Observatory (ARO) is situated in Algonquin provincial park, about 250 km north of Ottawa and is operated by the Geodetic Survey Division (GSD) of Natural Resources Canada in partnership with the Space Geodynamics Laboratory.

The antenna is involved in a large number of international geodetic VLBI sessions each year and is a key site in the ongoing Canadian S2 developments. The ARO is the most sensitive IVS Network Station.

This report summarizes recent activities at the Algonquin Radio Observatory.

Figure 1. Algonquin Radio Observatory 46m Antenna

1. Overview

The ARO 46 m antenna was used in the first successful VLBI experiment in 1967 and was involved as early as 1968 in geodesy, when the baseline length between the ARO and a telescope in Prince Albert, Saskatchewan was measured to be 2143 km (sigma=20m).

The GSD also maintains a permanent GPS monitoring station at Algonquin which is used by all IGS Analysis Centers as a fiducial reference. Satellite laser ranging and absolute gravity observations are also available for the site which is located on the stable pre-cambrian Canadian Shield. Local site stability has been monitored regularly using a high-precision network.

2. Site Improvements

In order to improve the operational performance of Algonquin, GSD undertook a major upgrade of the antenna control system which was completed in 1997.

This antenna control system still uses the original azimuth and elevation encoders to determine antenna position. We have made some progress in the effort to upgrade these and efforts continue in a manner that will not affect scheduled operations.

ARO upgraded to a Mark 5 Disk recording system in May of 2004, and has operated in 1 Gbps sessions.

Routine maintenance of the NR maser was completed in September, upgrades of the power supplies were done at the same time.

Figure 2. Visiting neighbours

3. General Specifications

- Latitude : N 45° 57' 19.812"
- Longitude : E 281° 55' 37.055"
- Elevation : 260.42m
- Reflector : 46m diameter with first 36.6m made of 0.634cm steel plates surrounded by 4.6m of steel mesh.
- Foci : S and X band at prime focus. Gregorian capability with 3m elliptical subreflector.
- Focal length : 18.3m (prime focus)
- Focal ratio : f/D = 0.4 for full surface and 0.5 for solid surface.
- Surface accuracy : 0.32cm for solid portion and 0.64 for mesh.
- Beamwidth : 3.0 arcmin at 3cm wavelength (10Ghz)
- Azimuth speed : 24 degrees per minute

- Elevation speed : 5 degrees per minute
- Receiver : S and X cryogenic receiver.
- VLBI equipment : VLBA4 with thin tape drive and Mark 5 Disk recorder. S2 DAS and RT.
- PCFS version : 9.6.9
- Time standard : NR Maser
- GPS receiver : BenchMark
- Timing receiver : CNS clock

4. Antenna Survey

The antenna is surrounded by a high stability network made of thirteen concrete piers. This network has been precisely measured five times to obtain the geodetic tie between the VLBI, the GPS, and the SLR reference points with a precision of a few mm. The VLBI antenna itself requires a special indirect survey since the reference point cannot be accessed directly.

5. Algonquin Operations

Algonquin Radio Observatory is involved in several International VLBI networks. Geodetic VLBI activities are summarized below.

ARO has participated in pulsar observations in collaboration with SGL.

5.1. Sessions Performed January 1, 2004 - December 31, 2004

Session Type	Number of Sessions
R4	45
E3	12
R&D	5
T2	6
RVD	1
Total	69

Fortaleza Station Report for 2004

Pierre Kaufmann, A. Macílio Pereira de Lucena, Adeildo Sombra da Silva, Claudio E. Tateyama

Abstract

This is a brief report on the activities carried on at Fortaleza geodetic-VLBI Station (ROEN: Rádio Observatório Espacial do Nordeste), located in Eusébio, CE, Brazil, in 2004. Observing activities consisted of 73 VLBI sessions and continuous GPS monitoring recordings. Further results were obtained on the dynamics of quasar spatial structures. A new contract was signed between NASA and CRAAM, Mackenzie Presbyterian Institute and University to partially support the activities at ROEN until 2009. The contract was made under the auspices of an Agreement of Cooperation between NASA–representing research interests of NOAA and USNO–and the Brazilian space agency AEB.

1. Introduction

The Rádio Observatório Espacial do Nordeste, ROEN, located at INPE facilities in Eusébio, nearly 30 km east from Fortaleza, Ceará State, Brazil, began operations in 1993. Geodetic VLBI and GPS observations are carried out regularly, as contributions to international programs and networks. ROEN is part of the Brazilian space geodesy program which was initially conducted by CRAAE (a consortium of the Brazilian institutions Mackenzie, INPE, USP, and UNICAMP) in the early 1990s. During that time the antenna and instrumental facilities were erected, and it was the beginning of the activities sponsored by U.S. agency NOAA, Brazilian Ministry of Science, and Technology's FINEP agency. ROEN is currently coordinated by CRAAM, Center of Radio Astronomy and Astrophysics, Mackenzie Presbyterian University, São Paulo, in agreement with the Brazilian National Space Research Institute, INPE. A new contract was signed in May 2004 between NASA and CRAAM, Mackenzie Presbyterian Institute and University to partially support the activities at ROEN until 2009. The contract came into being under the auspices of an Agreement of Cooperation that was recently signed between NASA–representing research interests of NOAA and USNO–and the Brazilian Space Agency AEB. Part of the operational cost, staff, and support of infrastructure are provided by INPE and by Mackenzie.

2. Brief Description of ROEN Facilities

The largest instrument of ROEN is the 14.2 m radio telescope, on one alt-azimuth positioner. It is operated at S- and X-bands, using cryogenic radiometers. The system is controlled by Field System, Version 9.6.2 program. Observations are recorded with a Mark III data acquisition system. One Sigma-Tau hydrogen maser clock standard is operated at ROEN.

GPS monitoring is performed by one dual frequency GPS Rogue receiver operated continuously. The collected data are provided to the IGS center, as well to Brazilian IBGE center. ROEN has all basic infrastructure for mechanical, electrical and electronic maintenance of the facilities.

3. Space Geodesy Team

The Brazilian space geodesy program is coordinated by Prof. Pierre Kaufmann, from São Paulo main office at CRAAM(CRAAE)/Instituto and Universidade Presbiteriana Mackenzie, re-

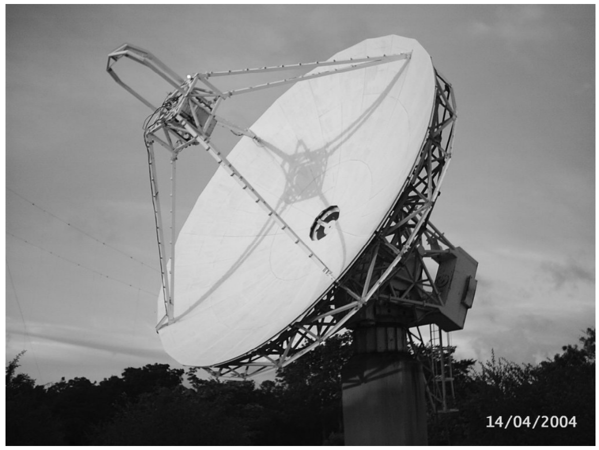

Figure 1. The 14.2-m antenna of Fortaleza (Eusébio) station

ceiving scientific assistance from Dr. Claudio E. Tateyama, and partial administrative support from Valdomiro S. Pereira and Neide Gea. Partial technical assistance is given by Itapetinga Radio Observatory staff, near São Paulo, also operated by INPE/Mackenzie.

The Fortaleza Station facilities and geodetic VLBI and GPS operations are managed on site by Eng. A. M. P. de Lucena (CRAAE/INPE), assisted by Eng. Adeildo Sombra da Silva (CRAAE/Mackenzie), and technician Avicena Filho (CRAAE/INPE). A position of an electronic technician was in the process of being filled.

4. Geodetic VLBI Observation

Fortaleza participated in the following geodetic VLBI experiments, as detailed in the table below for the year 2004.

Experiment	Number of Sessions
IVS-R4	50
IVS-T2	11
IVS-CRF	03
IVS-OHIG	07
IVS-R&D	02

5. Development and Maintenance Activities in 2004

Considerable attention was given to technical maintenance problems, specially to the following ones:

1. Tests and electrical alignment of the DC motors in both axes.
2. Installation of Mark IV formatter.
3. Repair on cryogenic system with replacement of cold head and helium lines.
4. Repairs on the following circuits, modules, or systems: Mark III video converters, Mark III

power supplies, Mark III IF3 module and Mark IV formatter.

5. Maintenance of web site (http://www.roen.inpe.br).

6. GPS Operation

The IGS network GPS receiver operated regularly at all times during 2004. Data were collected and uploaded to IGS/NOAA computer.

7. Visitors

In 2004 Mr. William T. Wildes, VLBI Network Manager at GSFC/NASA, visited ROEN for final discussions on the application plan of the new contract between NASA and Mackenzie. The contract was signed in May. The Rector of Mackenzie Presbyterian University, Professor Manasses C. Fonteles, visited ROEN in order to discuss the establishment of a cooperative agreement with Ceará State University, from Fortaleza, that is aimed at providing further support to ROEN and to the development of joint research on space geodesy-related fields, with emphasis on the exploration of GPS- and VLBI-derived meteorology parameters.

8. VLBI-related Research on Astrophysics

The astrophysics research work was continued with the participation of the student Danilo M. Teixeira. Using geodetic VLBA data it was shown for the first time a direct evidence of precession of the jet of OJ287 which before was only deduced from models of observations of a light curve. A study was started on the structure of compact sources; the quasar 0552+398 in particular shows a very complex structure which appears to be a combination of an extended component (1 mas in diameter) and a core-jet structure (1 mas in size). Plans have been established to use more extensively the geodetic VLBI data available at USNO, in cooperation with Kerry Kingham, not only to extend the present research but also to explore properties of other interesting sources.

9. Future Plans

It is planned to complete the Mark IV updating during 2005. The Mark IV formatter module was installed at the beginning of 2004. It is necessary to install new filter boards and upgrade the mixer board in the video converters to accomplish the Mark IV upgrading. The installation of a Mark 5 recorder unit is planned for 2005.

10. Publications

Tateyama, C.E. and Kingham, K.A.: "Structure of OJ287 from geodetic VLBA data", ApJ, 608, 149, 2004.

Teixeira, D.M., Tateyama, C.E., Kaufmann, P., de Lucena, A.M.P., Lister, M., Kingham, K.: "Observations of VLBI and VLBA of quasar 0552+398". Boletim da SAB, Vol. 24, No. 1, p. 156, 2004.

Gilmore Creek Geophysical Observatory

Steve Caskey

Abstract

The following report provides a general technical description and operational overview of the Gilmore Creek Geophysical Observatory located near Fairbanks, Alaska.

Figure 1. Gilmore Creek Geophysical Observatory's telescope and building, Fairbanks, Alaska.

1. GCGO at Fairbanks

Gilmore Creek Geophysical Observatory (GCGO) is located 22 km northeast of Fairbanks, Alaska. The observatory is co-located with the NOAA weather satellite command and data acquisition station. The station sits on an 8,500 acre reservation that is mostly undeveloped wilderness. Ten antennas are in operation. GCGO was instrumented by NASA's Crustal Dynamics Project in the mid 80's for the Alaskan mobile VLBI campaign and used as the base station for those geodetic measurements. The GCGO is part of the NASA Space Geodesy program in cooperation with the U.S. Naval Observatory.

2. Technical Parameters of GCGO

The 26 meter telescope, monument number 4047, X-East Y-North, latitude N 64° 58' 43.81288" and longitude E 147° 29' 42.18552" height 306.418 meters is hydraulic-operated and controlled by a Modcomp computer system (see Table 2). The DAT rack is a VLBA terminal and recorder (thin tape). The X/S band microwave receiver has a cryogenic low noise front end. VLBI Field System version 9.5.7 is used with a PC. Hydrogen Maser NR 5 is the time standard with an HP Cesium for the telescope computer. A CNS (TAC) receiver is monitored by the TAC32 software for GPS offset measurements. The JPL GPS scintillation project is observed using an Ashtech GPS receiver.The Institut Geographique National in France operates a DORIS beacon located near the NOAA VHF transmitter building. CLS from France operates the ARGOS and ARGOS-NEXT beacon. The ARGOS-NEXT platform is located next to the NOAA 26 meter antenna.

Table 1. Address of GCGO near Fairbanks.

Gilmore Creek Geophysical Observatory NOAA/NESDIS FCDAS 1300 Eisele Road Fairbanks, AK 99712 http://www.fcdas.noaa.gov

Table 2. Technical parameters of the GCGO radio telescope for geodetic VLBI.

Parameter	GCGO
owner and operating agency	NOAA/NASA
year of construction	1962
receiving feed	primary focus
diameter of main reflector	26 meters
focal length	10.9728 meters
surface accuracy of reflector	889 mm rms
X Y mount	1 degree per second
S-band	$2.2 - 2.4, GHz$
T_{sys}	$62\,K$
$SEFD(CASA)$	$650\,Jy$
G/T	$35.3\,dB/K$
X-band	$8.1 - 8.9, GHz$
T_{sys}	$58\,K$
$SEFD(CASA)$	$550\,Jy$
G/T	$44.5\,dB/K$

3. Staff of the Gilmore Creek Facility, Fairbanks, Alaska

GCGO is co-located with the NOAA Fairbanks command and data acquisition facility. The NOAA Manager is Lance Seman. The site is operated by Space Mark International with Roger Kermes acting as the Operations Manager and also as the Project Manager after the departure of Janine Jarvis. In May, technical staff member K. Eberhart was replaced with R. Morgan. S. Caskey also served on the GCGO technical staff during 2004 but is retiring in February, 2005. T. Knuutila, Z. Padilla, and others continue to assist the GCGO technical staff. The telescope's hydraulic system is maintained by M. Meindl, A. Sanders and F. Holan. Day by day scheduling is done by Cindy Thomas (NVI, Inc.) and VLBI technical directives/contract modifications by Bill Wildes (NASA/GSFC).

4. Status of Gilmore Creek Geophysical Observatory

In 2004 GCGO was scheduled for 100 sessions. In March, two were missed, due to an X encoder replacement and the repair of a crack in the X-axis structure. In May and June, six were missed due to an antenna TDPS failure. In addition, in July the BBC failed, and some observations were impacted. The BBC was repaired in August.

Starting in June, GCGO experienced a DEWAR warming problem, until a new coldhead was installed in December. Meanwhile, observations continued with the warm DEWAR. In October, we started troubleshooting an apparent MASER problem. In November, the last two LMR400 IF lines from the receiver failed, so we switched to backup RG-214 lines until two new LMR400 lines could be installed in December.

In November, we installed a new Ashtech GPS receiver and computer for the Rogue JPL system. In December, we installed the Mark IV(Formatter)/Mark5A(HD) system, the S2 DAR/RT system and a new antenna for the Rogue JPL system.

Visitors in 2004 included Clyde Cox (Honeywell, for Mark IV/Mark 5A and S2 installation), Irv Diegel (Honeywell, for MASER maintenance), Ed Himwich (NVI, Inc., for software upgrades) and Bill Wildes (NASA/GSFC, for contract purposes).

5. Outlook

Steve will retire on February 23, 2005. Thanks to all in the VLBI community for the 20+ years.

Goddard Geophysical and Astronomical Observatory

Jay Redmond, Charles Kodak

Abstract

This report summarizes the technical parameters and the technical staff of the VLBI system at the fundamental station GGAO. It also gives an overview about the VLBI activities during the previous year. The outlook lists the outstanding tasks to improve the performance of GGAO.

1. GGAO at Goddard

The Goddard Geophysical and Astronomical Observatory consists of a radio telescope for VLBI, SLR site to include MOBLAS-7, SLR-2000 (development system), a 48" telescope for developmental two color Satellite Ranging, a GPS timing and development lab, meteorological sensors and a H-maser. In addition, we are a fiducial IGS site with several IGS / IGSX receivers.

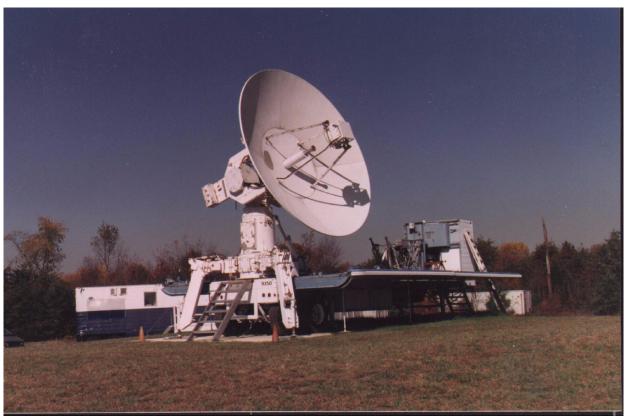

Figure 1. Old semi permanent MV-3 VLBI antenna.

Figure 2. New permanent MV-3 antenna.

GGAO is located on the east coast of the United States in Maryland. It is about 15 miles NNE of Washington D.C. in Greenbelt, Maryland (Table 1).

2. Technical Parameters of the VLBI Antenna at GGAO

The radio telescope for VLBI at GGAO (MV3) was originally built as a mobile or transportable station. It was previously known as Orion and was part of the original CDP. It is now being used as a fixed site having been moved to Goddard and semi-permanently installed here since the spring of 1991 as shown in Figure 1. In the winter of 2002 the antenna was taken off its trailer and permanently installed at GGAO as shown in Figure 2. The design criteria were

- transportability on two tractor trailers utilizing a 5 meter dish size to maximize receive and mobility considerations,
- setup of the radio telescope within eight hours (although it has been used as a fixed site since the spring of 1991)

Table 1. Location and addresses of GGAO at Goddard.

Longitude	76.4935° W
Latitude	39.0118° N
MV3 Code 299.0 Goddard Space Flight Center, (GSFC) Greenbelt, Maryland 20771	
http://www.gsfc.nasa.gov	

The technical parameters of the radio telescope are summarized in Table 2.

Table 2. Technical parameters of the radio telescope of GGAO for geodetic VLBI.

Parameter	GGAO-VLBI
owner and operating agency	NASA
year of construction	1982
diameter of main reflector d	$5m$
azimuth range	$0 \ldots 540°$
azimuth velocity	$3°/s$
azimuth acceleration	$1°/s^2$
elevation range	$0 \ldots 90°$
elevation velocity	$3°/s$
elevation acceleration	$1°/s^2$
X-band	$8.18 - 8.98\,GHz$
$receivingfeed$	$Cassegrainfocus$
T_{sys}	$24\,K$
$Bandwidth$	$800MHz, -2dB$
G/T	$32.1\,dB/K$
S-band	$2.21 - 2.45GHz$
$receivingfeed$	$primaryfocus$
T_{sys}	$19\,K$
$Bandwidth$	$240MHz, -2dB$
G/T	$21.2\,dB/K$
VLBI terminal type	MK4
recording media	thin-tape, Mark5
Field System version	9.7.1 (9.5 BETA)

3. Technical Staff of the VLBI Facility at GGAO

The GGAO VLBI facility gains from the experiences of the staff from the Research and Development VLBI support staff. GGAO is a NASA R&D and data collection facility, operated under contract by Honeywell Technology Solutions Incorporated (HTSI). Table 3 lists the GGAO station staff that are involved in VLBI operations.

Table 3. Staff working at the MV3 VLBI station at GGAO.

Name	Background	Dedication	Agency
Jay Redmond	engineering technician	100%	HTSI
Skip Gordon	engineering technician	20%	HTSI

4. Status of MV3 at GGAO

GGAO participated in several VLBI experiments which are listed in Table 4. In addition to the scheduled experiments listed in Table 4, MV3 has participated in several unscheduled experiments for VLBI developmental purposes and various other developmental activities.

Table 4. Participation of GGAO in VLBI Experiments from March 03, 2004 to December 7, 2004.

Date	Experiment
2004-03-03	RDV43
2004-04-13	T2028
2004-05-05	RDV44
2004-05-11	T2029
2004-06-15	T2030
2004-07-14	RDV45
2004-07-20	T2031
2004-08-17	T2032
2004-08-30	TSRT04
2004-09-14	T2033
2004-10-05	T2034
2004-10-06	RDV47
2004-11-16	T2035
2004-12-07	T2036

5. Outlook

GGAO will continue to support both scheduled experiments and developmental activities. The plan for 2005 consists of:

1. Continue testing of pre-release versions of PC-FS and new Linux kernel releases.
2. Continue with research on Mark 5 hardware development.
3. Continually striving to improve the performance of the entire MK4 data collection and station specific equipment.

4. MV-3 has installed the Mark 5 and e-VLBI hardware and has begun testing real-time from GGAO to Haystack. Correlation with the Westford data on the Mark 4 correlator was successful. (Oct 24, 2002).
5. The MV-3 antenna at GGAO has been permanently fixed to the ground and has been resurveyed. (Oct. 2003)

Hartebeesthoek Radio Astronomy Observatory (HartRAO)

Ludwig Combrinck, Marisa Nickola

Abstract

HartRAO, the only fiducial geodetic site in Africa, participates in VLBI, GPS and SLR global networks. This report provides an overview of our geodetic VLBI activities during 2004. The status of the 26m radio telescope surface upgrade is reported. In order to meet future requirements of geodetic VLBI, we have initiated the first steps towards founding a new space geodetic station which will cater to new developments and challenges as addressed by VLBI2010 and future requirements of GPS and SLR/LLR.

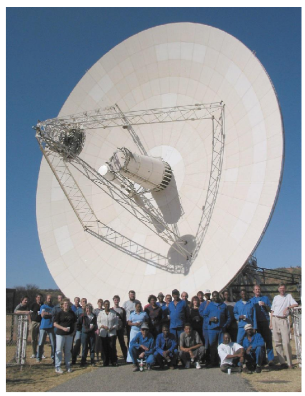

Figure 1. Staff celebrating in front of newly resurfaced telescope which the Director had just "launched" with champagne.

1. Geodetic VLBI at HartRAO

Hartebeesthoek is located 65 kilometers north-west of Johannesburg, just within the provincial boundary of Gauteng, South Africa. The nearest town, Krugersdorp, is 32 km distant. The telescope is situated in an isolated valley which affords protection from terrestrial interference. HartRAO uses a 26-metre equatorially mounted Cassegrain radio telescope built by Blaw Knox in 1961. The telescope was part of the NASA deep space tracking network until 1975 when the facility was converted to an astronomical observatory. The telescope is co-located with an SLR station (MOBLAS-6) and an IGS GPS station (HRAO). HartRAO joined the EVN as an associate member during 2001. Astronomical and geodetic VLBI have been allocated equal shares (15% each) of telescope time.

2. Technical Parameters of the VLBI Telescope of HartRAO

The feed horns used for 13 cm and 3.5 cm are dual circularly polarised conical feeds. The RF amplifiers are cryogenically cooled HEMTS. Tables 1, 2 and 3 contain the technical parameters of the HartRAO radio telescope, its receivers and recording systems. Our Mark 5 recording unit has been run in Mk5A mode since mid-May and has been used in the majority of experiments since then.

Table 1. Antenna parameters.

Parameter	**HartRAO-VLBI**
Owner and operating agency	HartRAO
Year of construction	1961
Radio telescope mount	Offset equatorial
Receiving feed	Cassegrain
Diameter of main reflector d	$25.914\,m$
Focal length f	$10.886\,m$
Focal ratio f/d	0.424
Surface error of reflector	$< 1.0\,mm$
Wavelength limit	$< 2.5\,cm$
Pointing resolution	$0.001°$
Pointing repeatability	$0.020°$

Table 2. Receiver parameters with dichroic reflector (DR), used for simultaneous S-X VLBI, off or on.

Parameter	**X-band**	**S-band**
T_{sys} (DR off) (K)	60	44
T_{sys} (DR on) (K)	70	50
S_{SEFD} (DR off) (Jy)	684	422
S_{SEFD} (DR on) (Jy)	1330	1350
Point source sensitivity (DR off) (Jy/K)	11.4	9.6
Point source sensitivity (DR on) (Jy/K)	19	27
3 dB beamwidth (°)	0.092	0.332

Table 3. VLBI recording systems.

Parameter	**HartRAO-VLBI**
VLBI terminal	MKIV
VLBI recorder	Mark5A, MarkIV, S2

3. Staff Members Involved in VLBI

Table 4 lists the HartRAO station staff who are involved in geodetic VLBI. Jonathan Quick (VLBI friend) has continued to provide technical support for the Field System as well as for hardware problems.

Table 4. Staff supporting geodetic VLBI at HartRAO.

Name	Function	Programme
Ludwig Combrinck	Programme Leader	Geodesy
Jonathan Quick	Hardware/Software	Astronomy
Marisa Nickola	Logistics/Operations	Geodesy
William Moralo	Operator	Geodesy
Pieter Stronkhorst	Operator	Geodesy
Attie Combrink	Operator	Geodesy
Gert Agenbag	Operator	Geodesy - student
Roelf Botha	Operator	Geodesy - student
Sakia Madiseng	Operator	Geodesy - student
Mojalefa Moeketsi	Operator	Geodesy - student
Sandile Ngcobo	Operator	Geodesy - student
Vasyl Suberlak	Operator	Geodesy - post doctoral researcher

4. Current Status

During 2004 HartRAO participated in 56 experiments (Table 5), compared to 58 in the previous year, which utilised the telescope time allocated to geodetic VLBI to its fullest extent. The antenna surface upgrade is continuing - new surface panels have been aligned optically using theodolite and steel tape, with a night alignment taking place on 2-3 September (see Figures 2, 3 and 4); the subreflector was realigned on 8-10 October. After completion of the night alignment, we will use microwave holography to determine the overall shape of the dish, making use of a 12 GHz transmitter on a geostationary satellite as a reference signal. Based on the results of the holography, individual panels will be adjusted to obtain the best overall surface shape.

Table 5. Geodetic VLBI experiments HartRAO participated in during 2004.

Experiment	Number of Sessions
R1	30
T2	6
CRDS	6
OHIG	4
SYOWA	4
CRF	4
RDV	2
Total	56

Figure 2. Night alignment of the 26-m antenna new surface panels; Cassegrain cone and 18 cm feed horn seen from top; theodolite reference target mounted beneath (removed) panel.

Figure 3. Jaques Grobler operating the theodolite located in the "elephant base" during the night alignment.

Figure 4. Jonathan Quick adjusts one of the mounting bolts.

5. Future Plans

We have started initial steps towards the development of a new integrated Space Geodesy Facility which will support SLR, LLR, VLBI and GPS as well as host other earth science instrumentation. This will mean the construction of a new site, development and implementation of new state of the art equipment and will place the southern hemisphere and especially Africa securely in the space geodesy arena for the next several decades. We would like to invite possible participants in this venture to contact us. The Geodesy Programme is an integrated programme, supporting VLBI, SLR and GPS and is active in several collaborative projects with GSFC, JPL, GFZ (Potsdam) and local institutes.

Hobart, Mt. Pleasant, Station Report for 2004

Brett Reid, Simon Ellingsen, John M. Dickey

Abstract

This is a brief report on the activities carried out at the Mt. Pleasant Radio Astronomy Observatory at Hobart, Tasmania. During 2004, the Observatory participated in 44 VLBI observing sessions with IVS.

1. Introduction

The Mt. Pleasant Observatory is located about 15 km north east of Hobart at longitude 147.5 degrees East and latitude 43 degrees South. The station is operated by the School of Mathematics and Physics at the University of Tasmania with financial support from the University and with the aid of an Australian Research Council (ARC) Linkage grant in conjunction with Geoscience Australia. The station has participated in geodetic VLBI programs since 1988 but only joined IVS in 2002 when we were able to secure funding support for geodetic observations for a five year period. The station has a co-located GPS receiver and a site which is used for absolute gravity measurements.

2. Brief Description of VLBI Facilities

The antenna is a 26m prime focus instrument with an X-Y mount. The focus cabin has recently been upgraded to include a feed translator with provision for four different receiver packages which enables rapid change over between geodetic and astronomical requirements. Standard receiver packages provide for operation at L band, S, C, X and K bands. There is also the dual frequency S/X geodetic receiver. All of these receivers are cryogenically cooled. The antenna has a maximum slew rate of 40 degrees per minute about each axis. The station is equipped with a Mark IV electronics rack and a Mark 5 VLBI recording system as well as S2 recorder. There is also another disk based recording system as used by other Australian VLBI antennas.

3. Staff

Staff at the observatory consisted of academics, Prof. John Dickey (director), Dr. Simon Ellingsen, Dr. Melanie Johnston-Hollitt and Prof. Peter McCulloch who has had a large input into the receiver design and implementation. Dr Giuseppe Cimó is a research fellow and has input into the Linux systems at the observatory. Mr. Brett Reid is the Observatory Manager whose position is funded by the university. In addition we have an electronics technical officer, Mr. Eric Baynes funded through the ARC grant and a half time mechanical technical officer. Mr Barry Wilson retired from the technical officer (mechanical) position and has been replaced by Mr. Geoff Tonta. For operation of the observatory during geodetic observations we rely heavily on support from astronomy PhD and post-graduate students.

Figure 1. The Mt Pleasant 26m antenna

4. Geodetic VLBI Observations

Hobart participated in 44 geodetic VLBI experiments during 2004. These were divided between the R1, OHIG, SYOWA, CRF, CRDS, T2, and APSG programs. All experiments, except SYOWA, were recorded using Mark 5. During some astronomy observations, formatter problems recording at the higher data rate of 512 Kb/s were discovered. Data from a few IVS experiments could not be correllated while repairs for bad synch and missing tracks were made to the formatter at Hobart. Our thanks go to the Haystack staff for advice on how to perform repairs to fix the formatter problems. A photogrammetry survey of the dish surface was performed in 2004. This survey was commissioned by Geoscience Australia and was looking particularly at gravitational distortions of the antenna.

5. Future Plans

As a part of the (ARC) linkage funding, we plan to have a PhD student in geodetic VLBI. The station's existing humidity, temperature and pressure sensors will be replaced in early 2005 by a more accurate MET3 sensor funded by NAOJ. This instrument has arrived and is installed and requires only the final implementation. Funding has been secured under ARC LEIF (Large Equipment and Infrastructure Funding) for a 10 Gb/s fibre optic link between the Mt. Pleasant VLBI site and the university campus to be installed by the end of 2005.

Kashima 34-m Radio Telescope

Eiji Kawai, Hiroshi Takeuchi, Hiromitsu Kuboki

Abstract

Communications Research Laboratory (CRL) was reorganized into National Institute of Information and Communications Technology (NICT) in April, 2004. NICT will operate Kashima 34-m radio telescope continuously as a facility of the Kashima Space Research Center. This is the network station report mainly focused on the telescope facilities.

1. Introduction

The Kashima 34-m telescope was constructed by National Institute of Information and Communications Technology (NICT), formerly Communications Research Laboratory (CRL) in 1988. The telescope is located about 100 km east of Tokyo. During 16 years of operation, the telescope has been kept in a fairly good condition and the antenna has participated in various VLBI and single-dish observations. The 34-m telescope is operated by the Radio Astronomy Applications Group of Kashima Space Research Center (KSRC).

Figure 1. The Kashima 34-m radio telescope.

2. Highlights

The S-band receiving frequency was expanded to receive 2040 MHz signal for observations of the Huygens probe to precisely measure the position of the probe by means of VLBI during its descent to Saturn's moon, Titan. System equivalent flux density was measured as 5400 Jy and system noise temperature was measured as 260 K at 2040 MHz. These values are not very good compared with the S-band receiver performance for the Kashima 34-m antenna, but the frequency of 2040 MHz is outside of the original receiver pass band and it seems there is a large signal loss due to the wave guide of the front-end system.

Table 1. Main specification of the 34-m Radio Telescope.

Main reflector aperture	34.073 m
Latitude	N 35° 57' 50.76"
Longitude	E 140° 39' 36.16"
Height of antenna center above sea level	43.6 m
Height of antenna position above sea level	26.3 m
Antenna shape	Modified Cassegrain
Mount shape	AZ-EL mount
Drive range azimuth (deg)	North ±270
Drive range elevation (deg)	7-90
Maximum speed azimuth (deg/sec)	0.8
Maximum speed elevation (deg/sec)	0.64
Operation wind speed (m/s)	13
Panel surface accuracy r.m.s. (mm)	0.17

In April 2004, NICT started the operation of the high speed research network test bed JGN II and KSRC became one of the access points of the network. 10 Gbps backbone connecting Kashima and Koganei Headquarter of NICT became available. Two GbE interfaces were installed at the access point at Kashima and we started to use the network for e-VLBI research and developments. Currently a data server is connected to the network and is used to store the K5 observation data from IVS sessions. The data are transferred and converted to Mark 5 format files for correlation processing by Haystack Observatory.

A new meteorological observation system was installed on December 5, 2003 replacing the old system. The old meteorological sensors were moved to the top of the observation building of the Kashima 34-m antenna. The new system is a WINS system of Meisei Corporation. Originally the system was capable of recording temperature, humidity, air pressure, wind speed, wind direction, and rain fall every 10 minutes. But the system was modified to record these data every minute. We started to use the new system in January, 2004.

3. Telescope Status

3.1. Receiver Systems

The receivers currently available at the Kashima 34-m telescope can observe on L,C,K,Ka,Q and S/X-band. The Ka and K-band receivers are integrated into a dual-band dewar. The receiver performances are summarized in Table 1. The polarization of the receiver is switchable to both RHCP and LHCP polarizations; the current setting is indicated by R or L. With the polarization fixed, it is still possible to change the polarization by changing the wave guide; this is indicated by R(L) or L(R). Ka-band efficiency in Table 1 is a provisional value. All receivers, except for the C-band receiver, are using cooled HEMT LNA which is kept around 12K physical temperature. The C-band LNA is using an ambient FET LNA.

To mitigate Radio Frequency Interference (RFI), additional filters were installed in the L and S-band receivers. For the S-band receiver, a High Temperature Superconductor (HTS) filter is used (see next section). Coaxial 11 sections usually employ a 1350-1450MHz bandpass filter for the L-band.

The IF (intermediate frequency) signals of the receivers are transmitted from the telescope to the observation room via optical fibers. Higher frequency band receivers (K, Ka, and Q) use an IF signal of 5-7 GHz. IF signal are converted to base band signal or other IF signal in the observation room.

Table 2. Receiver Specification of the 34-m Radio Telescope.

Band	frequency (Hz)	Trx (K)	Tsys (K)	Efficiency	SEFD (Jy)	Polarization
L	1350-1750	18	43	0.68	190	R/L
S	2193-2350	19	83	0.65	390	R/L
C	4600-5100	100	127	0.70	550	L(R)
X	7860-8680	41	52	0.68	230	R/L
K	21800-23800	75	160	0.5	970	L(R)
Ka	31700-33700	85	150	0.4	1100	R(L)
Q	42300-44900	180	300	0.3	3000	L

3.2. RFI Mitigation

Severe RFI at S-band due to third-generation mobile phone systems (IMT-2000) began to influence the Kashima 34-m antenna station in 2002 [1]. To mitigate the interference, we have developed a cooled HTS filter [2]. The sharp cutoff filter edge of -10 dB/MHz enables the reception of lower S-band adjacent to the IMT-2000 allocation. The filter is integrated into a maintenance free cryogenics cooler and is now continuously operating between LNA and the down-converter.

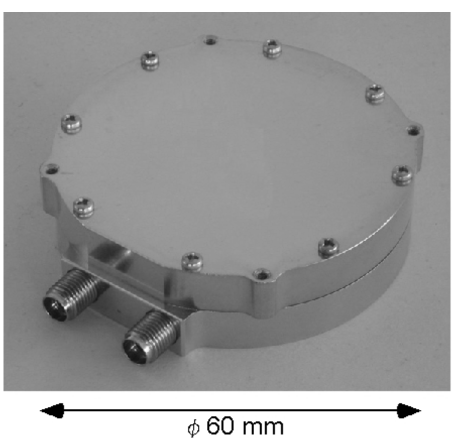

Figure 2. HTS filter

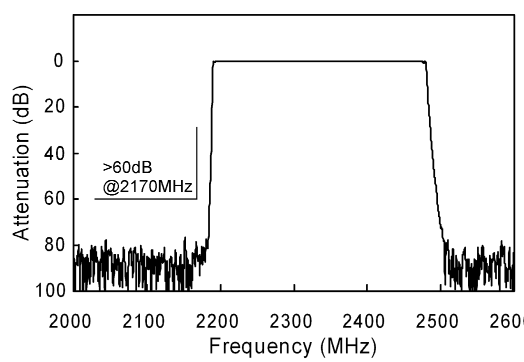

Figure 3. HTS filter specification

3.3. Mechanical System

The ACU had some failures due to its aging recently. For example, we have experienced EL axis hunting, servo mode exchange failure, and so on. To prevent observation failure, we prepared new ACU and it will be installed in January 2005. As the main reflector backup structure was corroded, repair painting and welding was performed in August and September, 2004. Additional repair work is planned for the month of February, 2005. Since a lot of repair work had to be done, repair time was used up after only two months. Replacement of the nut-plate, which fixes a main reflector to the backup structure, was also performed.

4. Technical Staff of the Kashima 34-m Radio Telescope

Engineering and technical staff of the Kashima 34-m telescope are Eiji Kawai (leader of all operations and maintenance), Yasuhiro Koyama (scientist and engineer of software and hardware), Mamoru Sekido (scientist and engineer of software and reference signal), Hiroshi Takeuchi (scientist and engineer of software and hardware), Kuboki Hiromitsu (technician of mechanical and RF related parts), and Tetsuro Kondo is the supervisor of the overall project.

References

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Kashima and Koganei 11-m VLBI Stations

Yasuhiro Koyama

Abstract

Two 11-m VLBI stations at Kashima and Koganei used to be a part of the Key Stone Project VLBI Network. The network consisted of four VLBI stations at Kashima, Koganei, Miura, and Tateyama. Since Miura and Tateyama stations have been transported to Tomakomai and Gifu, Kashima and Koganei 11-m stations are remaining as IVS network stations. Since regular VLBI sessions with the Key Stone Project VLBI network terminated in 2001, these stations are mainly used for the purposes of technical developments and various observations. In the year 2004, flux monitoring observations of binary black hole candidates were initiated in collaboration with Gifu University by using the Gifu-Kashim11 baseline. Many observations were also performed to determine precise orbit of the spacecraft Hayabusa.

1. Introduction

The Key Stone Project (KSP) was a research and development project of the National Institute of Information and Communications Technology (NICT, formerly Communications Research Laboratory) [1]. Four space geodetic sites around Tokyo were established with VLBI, SLR, and GPS observation facilities at each site. The locations of the four sites were chosen to surround Tokyo Metropolitan Area to regularly monitor the unusual deformation in the area (Figure 1).

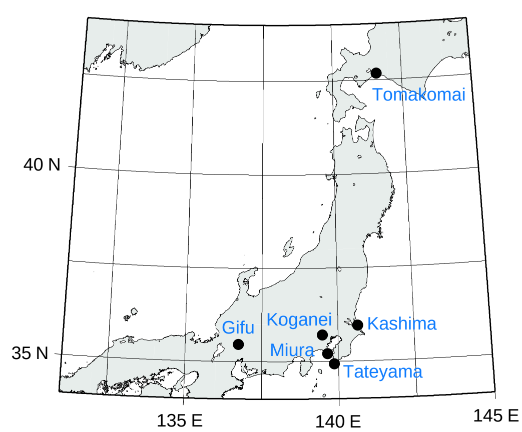

Figure 1. Geographic locations of four KSP VLBI stations and two stations at Tomakomai and Gifu.

Therefore, the primary objective of the KSP VLBI system was to determine precise site positions of the VLBI stations as frequently and fast as possible. To realize this objective, various new technical advancements were attempted and achieved. By automating all of the processes from the observations to the data analysis and by developing the real-time VLBI system using the high speed digital communication links, unattended continuous VLBI operations were made possible. Daily continuous VLBI observations without human operations were actually demonstrated and the results of data analysis were made available to the public users immediately after each VLBI session. Improvements in the measurement accuracies were also accomplished by utilizing fast slewing antennas and by developing higher data rate VLBI systems operating at 256 Mbps.

11-m antenna and other VLBI facilities at Miura and Tateyama stations have been transported to Tomakomai Experimental Forest of the Hokkaido University and to the campus of Gifu University, respectively. As a consequence, two 11-m stations at Kashima and Koganei (Figure 2) are remaining as IVS network stations. Since regular VLBI sessions with the Key Stone Project VLBI network terminated in 2001, the 11-m VLBI stations at Kashima and Koganei are mainly used for the purposes of technical developments and other observations.

Figure 2. 11-m VLBI antennas at Kashima (left) and Koganei (right).

2. Activities in 2004

For technical developments, the baseline between Kashima and Koganei is now used as a test bed for real-time VLBI observations based on the Internet Protocol (IP). Two stations used to be connected by high speed Asynchronous Transfer Mode (ATM) network in collaboration with the NTT Laboratories until July 2003. In April 2004, NICT started to operate the high speed research test-bed network called JGNII and both the Kashima and Koganei stations are connected to the JGNII backbone with OC-192 (10 Gbps) connection. JGNII is a follow-on project of the JGN (Japan Gigabit Network) which was operated by the Telecommunications Advancement Organization of Japan (TAO) for 5 years from 1999. Since the TAO was merged with Communications Research Laboratory to establish the NICT as a new institute, JGNII succeeded the JGN project. Whereas the JGN project was operated based on the ATM architecture, the new JGNII network uses mainly IP. One GbE (Gigabit Ethernet) interface is installed at Koganei station and two GbE interfaces are connected at Kashima station. This environment provides an ideal opportunity for e-VLBI research and developments.

The operating software of the antenna and VLBI observing system at Kashima 11-m station was updated from the Key Stone Project field system to the FS9 field system. Since the antenna control units of the Kashima and Koganei 11-m stations are identical to the old 26-m station at Kashima, the FS9 field system which was used at the 26-m station was copied and made available. Currently both the old field system and FS9 are available at the Kashima 11-m station and we are planning to install FS9 also at the Koganei 11-m station.

In the year 2004, flux monitoring observations of binary black hole candidates were initiated with the baseline between Gifu (11-m) and Kashima (11-m) stations. This project is a joint effort of NICT and Gifu University. The purpose of the project is to monitor the flux density of black hole binary candidate sources by means of VLBI to detect flux density variation due to the orbital motion of the binary system. For this purpose, K5/VSSP systems are used at both stations and the data are correlated by the K5 software correlator program. Many observations were also performed to determine precise orbit of the spacecraft Hayabusa. The spacecraft was launched by Japan Aerospace Exploration Agency on May 9, 2003 to approach the asteroid Itokawa. The X-band telemetry signal from the spacecraft is used to demonstrate precise orbit determination by means of differential VLBI observations. Since precise orbit determination of the spacecraft Hayabusa is required to efficiently navigate the spacecraft to approach the asteroid Itokawa, many VLBI stations in Japan including the 11-m VLBI stations at Kashima and Koganei participated in the observations. The spacecraft Hayabusa is expected to arrive at the asteroid Itokawa in 2005 and precise orbit determination of the spacecraft will be essential to make the mission successful. In 2004, several observations were made mainly to survey adequate celestial radio sources for differential VLBI observations to be used in the critical observations which will be performed in 2005.

In addition, two sessions listed in Table 1 were performed in 2004. The tsrt04 session is a real-time e-VLBI demonstration session with four VLBI sites at Kashima (11-m), Westford (18-m), Onsala (20-m), and GGAO (5-m). All stations are connected to the high speed research Internet and the real-time data transfer of observed data was challenged. The tec04259 session was performed to obtain Total Electron Content (TEC) data by means of VLBI. The purpose of the session is to compare the TEC results from the VLBI session with the TEC value evaluated from the global ionospheric model.

Table 1. R&D VLBI sessions conducted in 2004.

Session	Date	Participating stations
tsrt04	August 30	Kashima (11-m), Westford (18-m), Onsala (20-m), GGAO (5-m)
tec04259	September 15	Kashima (11-m), Mizusawa (20-m), Gifu (11-m)

3. Staff Members

The 11-m antenna stations at Kashima and Koganei are operated and maintained by the Radio Astronomy Applications Group at Kashima Space Research Center, NICT. The staff members of the group are listed in Table 2. The operations and maintenance of the 11-m VLBI station at Koganei is also greatly supported by the Optical Space Communications Group and Quasi-Zenith Satellite System Group at Koganei Headquarters of NICT. We are especially thankful to Jun Amagai and Futaba Katsuo for their support.

Table 2. Staff members of the Radio Astronomy Applications Group, KSRC, NICT

Name	Main Responsibilities
Tetsuro KONDO	Group Leader
Eiji KAWAI	Antenna System
Yasuhiro KOYAMA	International e-VLBI
Ryuichi ICHIKAWA	Spacecraft Orbit Determination
Junichi NAKAJIMA	VLBI System Developments
Mamoru SEKIDO	Spacecraft Orbit Determination
Hiroshi TAKEUCHI	VLBI System Developments
Moritaka KIMURA	VLBI System Developments
Hiromitsu KUBOKI	Antenna System
Thomas HOBIGER	Visiting Researcher
Eric VIDAL	Visiting Researcher
Jose ISHITSUKA	Visiting Researcher

4. Future Plans

The S/X receivers of the 11-m antenna at Tomakomai was removed and will be replaced by a new 22 GHz receiver. As a result, CUTE sessions will only be performed with three VLBI stations at Kashima, Koganei, and Gifu. 22 GHz VLBI observations, on the other hand, will be made with the Kashima 34-m VLBI station and the Tomakomai 11-m VLBI station once the new 22 GHz receiver is installed at the Tomakomai station.

In 2005, we are planning to continue VLBI observations toward the spacecraft Hayabusa for its precise orbit determination. The use of phase delay measurements will be investigated to improve the accuracy and precision of the determination of the orbit.

References

[1] Special issue for the Key Stone Project, J. Commun. Res. Lab., Vol. 46, No. 1, March 1999

[2] Koyama, Y., T. Kondo, H. Osaki, K. Takashima, K. Sorai, H. Takaba, and K. Fujisawa, IVS CRL TDC News, No. 23, Nov. 2003, pp. 26-30

Kokee Park Geophysical Observatory

Clyde A. Cox

Abstract

This report summarizes the technical parameters and the technical staff of the VLBI system at Kokee Park on the Island of Kauai. Included is an overview of the VLBI activities for the year 2004.

1. KPGO

Kokee Park Geophysical Observatory is located on the Island of Kauai in the Hawaiian Islands; Kauai is the most northwestern (inhabited) Island. The site is in a State Park (Kokee State Park) hence its name. It is located at an elevation of 1100 meters near the Waimea Canyon, which is often referred to as the Grand Canyon of the Pacific.

Kokee Park Geophysical Observatory first participated in VLBI operations as part of the GAPE experiments in 1984. At that time the station was part of NASA's STDN (Satellite Tracking Data Network). The 9-m system was modified by installing a focal point receiver, hydrogen maser, data acquisition terminal, tape drive and computer system. This was operational for the summer of 1984. The system was removed after the GAPE '84 experiments and reinstalled again for the summer of 1985. It was not until 1986 that we became a continuous participant in VLBI operations.

In October 1989 NASA phased out the STDN operation on Kauai and the station was transferred to the Crustal Dynamics Project at the Goddard Space Flight Center. The station started weekly operation for the U.S. Naval Observatory as part of the NAVNET network.

Early in 1992 construction of USNO's present 20-meter antenna was started. The foundation work was completed in August 1992 and the structure was started in September just as Hurricane Iniki struck on September 11, 1992. Installation was completed in 1993 and first light was in June 1993. Later in 1993 the use of the 9-meter system was discontinued.

Starting in July 2000 Kokee Park began daily (Monday through Friday) participation in the Intensive schedule for USNO.

S-2 recorder system was installed in 2000.

Mark IV system was installed during 2001.

In May of 2002 Mario Bérubé and Bill Petrachenko arrived on site for installation and testing of a S-2 DAS. We have since that time supported the E-3 series of experiments on a monthly basis.

In May of 2002 Kokee Park received a Mark 5 system which was first run in parallel with the tape drive during the daily Intensive sessions (three times a week). Correlation was first done at Haystack; after several weeks of comparison we then started to ship the disk to USNO. During CONT02 the Mark 5 was used in stand alone mode. Switching between Intensive sessions and other experiments became a pleasure.

During November 2002 the survey team was on station to verify our antenna footprint and to survey the new (replacement) Doris beacon antenna.

A new MET package (MET3) was installed in February 2003.

Mid 2004 we started having problems with our Azimuth Gear Reducers. One has been removed and shipped back to the manufacturer for refurbishment, and an additional unit is under procurement.

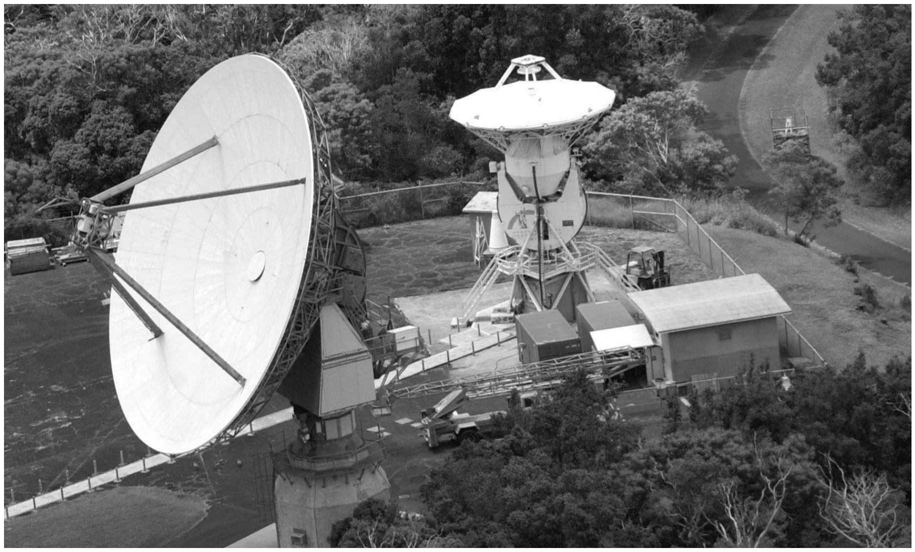

Figure 1. Kokee Park Geophysical Observatory 9m & 20m antennas.

Table 1. Location and Addresses of Kokee Park Geophysical Observatory

Longitude	159.665° W
Latitude	22.126° N
Kokee Park Geophysical Observatory P.O. Box 538 Waimea, Hawaii 96796 USA	

2. Technical Parameters of the VLBI System at KPGO

The receiver is of NRAO (Green Bank) design (dual polarization feed using cooled 15 K HEMT amplifiers). The DAR rack and tape drive were supplied through Green Bank. The antenna is of the same design and manufacture as those used at Green Bank and Ny-Ålesund.

The technical parameters of the radio telescope are summarized in Table 2.

Timing and frequency is provided by a Sigma Tau Maser with a NASA NR Maser providing backup. Monitoring of the station frequency standard performance is provided by a CNS (GPS) Receiver/Computer system. The Sigma Tau performance is also monitored via the IGS Network.

3. Technical Staff of the VLBI System at KPGO

The staff at Kokee Park consists of six people who are employed by Honeywell under contract to NASA for the operations and maintenance of the Observatory. VLBI operations are conducted by Kelly Kim, Matt Harms, and Kawika Fujita.

Table 2. Technical parameters of the radio telescope at KPGO.

Parameter	Kokee Park
owner and operating agency	USNO-NASA
year of construction	1993
radio telescope system	Az-El
receiving feed	primary focus
diameter of main reflector d	$20m$
focal length f	$8.58m$
f/d	0.43
surface contour of reflector	$0.020 inches rms$
azimuth range	$0 \ldots 540°$
azimuth velocity	$2°/s$
azimuth acceleration	$1°/s^2$
elevation range	$0 \ldots 90°$
elevation velocity	$2°/s$
elevation acceleration	$1°/s^2$
X-band (reference $\nu = 8.4GHz, \lambda = 0.0357m$)	$8.1 - 8.9\, GHz$
T_{sys}	$40\, K$
$S_{SEFD}(CASA)$	$900\, Jy$
G/T	$45.05\, dB/K$
η	0.406
S-band (reference $\nu = 2.3GHz, \lambda = 0.1304m$)	$2.2 - 2.4GHz$
T_{sys}	$40\, K$
$S_{SEFD}(CASA)$	$665\, Jy$
G/T	$35.15\, dB/K$
η	0.539
VLBI terminal type	VLBA/VLBA4-MARK5
recording media	thin-tape only
Field System version	9.6.9

4. Status of KPGO

Kokee Park has participated in many VLBI experiments since 1984. We started observing with GAPE, continued with NEOS and CORE, and are now in IVS R4 and R1. We also participate in the RDV experiments.

We averaged 1.5 experiments per week during calendar year 2000 and increased to an average of 2 experiments of 24 hours each week with daily Intensive experiments during year 2002 and into 2005.

Kokee Park also hosts other geodetic measurement systems, including PRARE, a DORIS beacon, and a Turbo-Rogue GPS receiver. Kokee Park is an IGS station.

5. Outlook

e-VLBI was expected to make its debut during the first part of 2003. However, we are delayed due to the common "last Mile" problem.

Upgrading of our SX Receiver and its Interface Drawer is awaiting arrival of parts.

New Field System computer expected on line very soon.

Figure 2. Kokee Park also hosts other systems; DORIS Beacon, PRARE, and IGS (GPS).

Matera CGS VLBI Station

Giuseppe Colucci, Domenico Del Rosso, Luciano Garramone

Abstract

This report describes the status of the Matera VLBI station[1], after the major hardware failure happened at the beginning of 2004. Also an overview of the station, some technical characteristics of the system and staff addresses will be given.

1. General

The Matera VLBI station is located at the Italian Space Agency "Centro di Geodesia Spaziale" (CGS) near Matera, a small town in the South of Italy. The CGS came into operation in 1983 when

Figure 1. The Matera "Centro di Geodesia Spaziale" (CGS)

a Satellite Laser Ranging SAO-1 System was installed at CGS. Fully integrated in the worldwide network, SAO-1 has been in continuous operation from 1983 up to 2000, providing high precision ranging observations of several satellites. The new Matera Laser Ranging Observatory (MLRO), the most advanced Satellite and Lunar Laser Ranging facility in the world, has been installed in 2002 and has replaced the old SLR system. CGS hosted also mobile SLR systems MTLRS (Holland/Germany) and TLRS-1 (NASA).

In May 1990 the CGS extended its capabilities to Very Long Baseline Interferometry (VLBI) installing a 20-m radiotelescope. Since then, Matera performed 634 sessions up to December

2003. In 1996 the receiver was upgraded to standard wideband and at the end of 1999 a Mark IV formatter and decoder were installed by MIT Haystack.

In 1991 we started GPS activities, participating in the GIG 91 experiment installing in Matera a permanent GPS Rogue receiver. In 1994 six TurboRogue SNR 8100 receivers were purchased in order to create the Italian Space Agency GPS fiducial network (IGFN). At the moment 12 stations are part of the IGFN and all data from these stations, together with 24 other stations in Italy, are archived and made available by the CGS WWW server GeoDAF (http://geodaf.mt.asi.it).

Thanks to the colocation of all precise positioning space based techniques (VLBI, SLR, LLR and GPS), CGS is one of the few "fundamental" stations in the world. With the objective of exploiting the maximum integration in the field of Earth observations, in the late 1980s ASI extended CGS involvement also in remote sensing activities for present and future missions (ERS-1, ERS-2, X-SAR/SIR-C, SRTM, ENVISAT).

2. Technical/Scientific

The Matera VLBI antenna is a 20-meter dish with a Cassegrain configuration and AZ-EL mount. The AZ axis has ±270 degrees of available motion. The slewing velocity is 2 deg/sec for both AZ/EL axis.

The technical parameters of the Matera VLBI antenna are summarised in Table 1.

The Matera time and frequency system is composed of three frequency sources (two Cesium beam and one H-maser standard) and three independent clock chains. The EFOS-8 H-maser from Oscilloquartz is used as a frequency source for VLBI.

The control computer is a SWT Pentium/233 PC running Linux and FS version 9.6.9.

Table 1. Matera VLBI Antenna Technical Specifications

Input frequencies	S/X	2210 MHz to 2450 MHz / 8180 MHz to 8980 MHz
Noise temperature at dewar flange	S/X	<20 K
IF output frequencies	S/X	190 MHz to 430 MHz / 100 MHz to 900 MHz
IF Output Power with 300 K at the input flange	S/X	0.0 dBm to +8.0 dBm
Gain compression	S/X	<1 dB at +8 dBm output level
Image rejection	S/X	>45 dB within the IF passband
Inter modulation products	S/X	At least 30 dB below each of 2 carriers at an IF output level of 0 dBm per carrier
T_{sys}	S/X	55/65 K
SEFD	S/X	800/900 Jy

3. Staff

The list of the VLBI staff members of Matera VLBI station is provided in Table 2.

Table 2. Matera VLBI staff members

Name	Agency	Activity	E-Mail
Ing. Luciano Garramone	ASI	VLBI Manager	luciano.garramone@asi.it
Domenico Del Rosso	Telespazio	Operations Manager	domenico_delrosso@telespazio.it
Giuseppe Colucci	Telespazio	VLBI contact	giuseppe.colucci@asi.it

Figure 2. Rail at one of the damaged points (concrete was manually removed)

4. Status

During 2004, the Matera Station did not acquire any data due to a major antenna failure. During periodical tests, an abnormal rail movement was noted and 2 out of 8 rail segments resulted not properly in-line. A temporary fix was attempted, but after few acquisition sessions, another dangerous problem was noted on a different rail segment. At this point, the rail tended to move radially because of some problem with the concrete (see Figure 2). Additional tests revealed that the rail was irregularly worn too, so it was decided to replace it with a totally new rail (of different shape). Figure 3 shows the present and new project rail shape.

5. Outlook

In summary, the following steps are planned in order to have a complete new rail system for the antenna:
- replacement of the 4 wheels to adapt them to the new rail shape
- replacement of the rail and of the concrete under it (using high quality grout)
- upgrade of the rail-concrete interface
- set up of a new concrete ring around the rail in order to have more stability.

Before and after all these steps, a detailed local survey on the antenna is also planned.

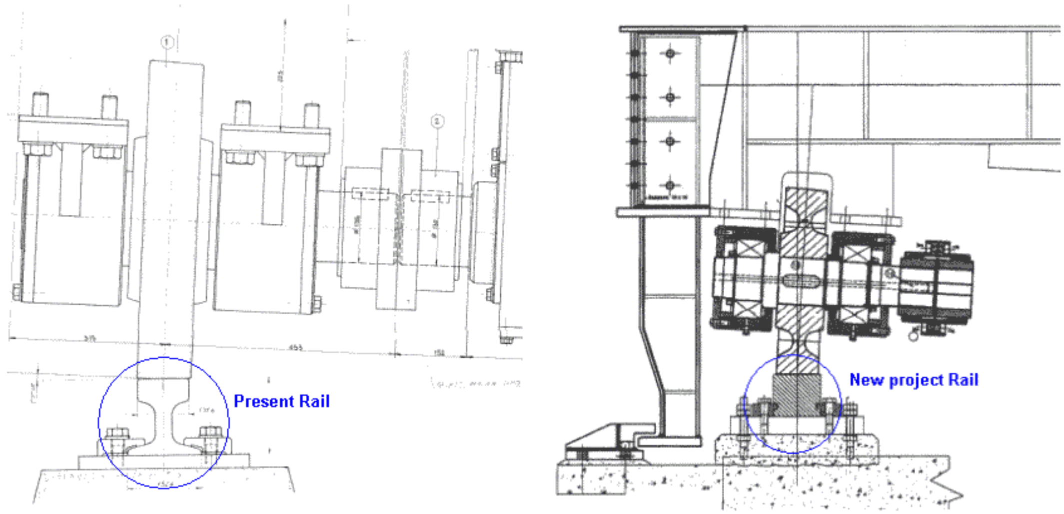

Figure 3. Present and new project rail shape (different scales)

Due to the extent of the works, they will not be finished before the end of 2005.

References

[1] G.Colucci, D.Del Rosso, E.Lunalbi, M.Paradiso: "Matera VLBI Station Report on the Operational and Performance Evaluation Activities from January to December 2003", available soon at this address: http://geodaf.mt.asi.it/html/surv_rep.html

The Medicina Station Status Report

Alessandro Orfei, Giuseppe Maccaferri, Andrea Orlati, Franco Mantovani

Abstract

General information about the Medicina Radio Astronomy Station, the 32 m antenna status and the staff in charge for VLBI observations, are provided. In 2004 the data from geodetic VLBI observations were mainly acquired using the MK5A recording system with good results. The station participation in geodetic VLBI observations increased this year compared to previous years.

1. The Medicina 32 m Antenna. General Information

The Medicina 32 m antenna is located at the Medicina Radio Astronomy Station. The station is run by the Istituto di Radioastronomia and is located about 33 km East of Bologna. The Consiglio Nazionale delle Ricerche was the funding agency of the Istituto di Radioastronomia till the end of 2004. From January 1st, 2005 the funding agency will be the Istituto Nazionale di Astrofisica (INAF).

The antenna, inaugurated in 1983, since 1985 takes regularly part in IVS observations. A permanent GPS is installed in the vicinity. The antenna is also one part of the European VLBI Network.

Figure 1. View of the Medicina 32 m dish taken during geodetic VLBI observations. Note that the subreflector is shifted to allow the use of the S/X receiver located in the primary focus of the radio telescope.

2. Antenna Description

The Medicina antenna has a Cassagrain optics, consisting of a primary mirror of 32 m in diameter, and a secondary mirror, called subreflector, of convex shape and about 3 m in diameter. The subreflector, mounted on a quadrupode, is placed opposite the primary mirror, and focuses the radio waves at its centre, where the receiver system is located. For some observing frequencies, a simplified optical system is enough. The subreflector is therefore shifted from its normal position, and the receiving system is placed at the primary focus. The antenna can operate in the range between 327 MHz and 22 GHz.

The receivers are cooled with cryogenic techniques to improve the system sensitivity. The antenna is flexible in changing the operative receiver: only few minutes are needed to change the observing frequency. A picture of the antenna, which was taken recently, is shown in Figure 1.

3. The Staff

Many scientists and technicians are taking care of the observations. However, there is a restricted number of people that is dedicated to maintain and improve the reliability of the antenna during the observations: Alessandro Orfei is the Chief Engineer, expert in micro-wave receivers; Giuseppe Maccaferri is the Technician in charge of the telescope's backend; Andrea Orlati is the Software Engineer who takes care of the observing schedules and regularly implements SKED&DRUDG and the Field System.

4. Current Status and Activities

At the beginning of 2004 the Field System version 9.7.1 was installed. The next release (9.7.2) was installed in December, after the European VLBI Network session 3/2004 in November.

The Mark 5A recording system works fine. Many observations were recorded both for astronomy (during the EVN Sessions) and geodesy with good results. A complete set of 5 modules with 8x120GB hard disks and 21 modules with 8x250GB have been made available for VLBI recording. 41840 Gb are allocated for astronomy and 8988 Gb for geodetic VLBI.

4.1. Front-end and Back-end Upgrading

The prototyping of new cryogenic Low Noise Amplifiers is in progress. At present, 18–26 GHz hybrid GaAs LNAs and InP MMIC chips are available. The latter have to be bonded and embedded in connected enclosures. The designs of 28–40 GHz, 33–50 GHz and W band (around 90 GHz) LNAs are in progress by using the monolithic solution with InP technology. The expected delivery of the chips is foreseen in spring 2006. A 4.3–5.8 GHz hybrid LNA is under construction as well.

The upgrade of the polarimetric system has been completed and a software package for making raster scan observations is being tested.

4.2. Optic Fiber Link

The Institute of Radioastronomy, the Emilia-Romagna Regional Government and GARR (Italian Academic and Research Network) have signed an agreement under which the Regional Government will provide a fiber optic link at 1 Gb/s between the Medicina Station and the GARR backbone in Bologna. The connection is planned for spring 2005.

5. Geodetic VLBI Observations

During 2004, the Medicina 32 m dish has taken part in 27 geodetic VLBI observations, namely 4 IVS–T, 5 RDV, 14 R and 4 EUROPE projects. Some of the above projects were observed by Medicina as substitute for the Matera antenna, which was stopped by failure in the azimuth rail. This was agreed upon request by the IVS Coordinating Center.

Report of the Mizusawa 10m Telescope

Seiji Manabe, Osamu Kameya, Kenzaburo Iwadate, Takaaki Jike

Abstract

The status and activities of the Mizusawa 10m VLBI telescope are reported.

1. General Information

There are two radio telescopes dedicated to VLBI at Mizusawa. These antennas are shown in Figure 1. One is the 10m telescope which has been registered as an IVS network station telescope. The other is the 20m dual-beam telescope which is part of the VERA (VLBI Exploration of Radio Astrometry) network together with three other telescopes deployed at Iriki, Ogasawara and Ishigakijima, respectively. This telescope has not been registered as an IVS network station. The 10m telescope once participated in international geodetic VLBI observations, namely IRIS-P. However, in recent years it was used only for domestic observations, namely, domestic geodetic observations with the 32m telescope of the Geographic Survey Institute. After the VERA geodetic observation system became fully operational in November, 2004, the 10m antenna passed its geodetic mission to the VERA 20m telescope. However, only the 10m antenna will be described in the following since the 20m telescope is operated in the framework of the VERA project and it is not yet ready to report its activities to the IVS.

Table 1. General information of the Mizusawa 10m telescope

Sponsoring agency	VERA Observatory, National Astronomical Observatory of Japan
Contribution type	Network observing station
Location	39 8 1412(N) 141 7'56.4518 (E) 111.048m(H) in WGS84

2. Component Description

Main specifications of the 10m telescope are summarized in Tables 2 and 3.

3. Staff

There are seven staff members working for the 10m telescope. Other staff members of the VERA observatory also contribute to observations.

4. Activities in 2004

The activities in 2004 can be divided into three groups. The first group encompasses the geodetic observations to continue monitoring the position of Mizusawa. This class of observations was performed by joining the JADE sessions of the GSI. The second one is simultaneous observations

Figure 1. The Mizusawa 10m antenna (left) and the 20m VERA antenna (right)

Table 2. Antenna parameters

Diameter	10m		
Mount	Azimuth-Elevation		
Surface accuracy	0.34mm(rms)		
	S	X	K
HPBW	54'	13'	5.2'
Aperture efficiency	38%	63%	36%
Beam efficiency	55%	73%	
Slew	Azimuth	Elevation	
range	180+/-267	3–90	
speed	3.14/sec	3.06/sec 2	
acceleration	3.78/sec 2	3.71	
Pointing accuracy	<1'(rms)	<1'(rms)	

Table 3. Receiver specifications

Frequency band	Frequency range(GHz)	Receiver temperature(K)	Tsys(K)	Polarization	Receiver type
S	2.15—2.35	50	340	RHC/LHC	FET
X	8.13—8.60	55	103	RHC	HEMT
K	19.5—25.0	80	150	RHC/LHC, Linear	cooled HEMT

Table 4. Staff

Chief	Osamu Kameya
Scientist	Yoshiaki Tamura, Takaaki Jike, Seiji Manabe
Chief engineering technician	Kenzaburo Iwadate
Engineering technician	Seisuke Kuji, Katsuhisa Sato

with the 20m telescope to calibrate differential fringe phases between two beams of the 20m telescope. In these observations each beam observes a common radio source alternately by switching the antenna pointings while the 10m telescope continues its observation without interruption. The third one consists of experiments that prepare the Japanese lunar exploration project SELENE in which the Mizusawa group is undertaking the RISE project. The RISE project applies space geodetic techniques for exploring lunar gravity field and surface topography with unprecedented accuracy. Differential VLBI technique is one of the key observational technologies to achieve the aimed accuracy. There were some additional observations such as observations of stability of atmospheric phase fluctuations. The telescope was also used as a single dish antenna for monitoring maser sources in the Orion KL region.

The X-band receiver was renewed and the nominal system temperature decreased from 130K to 103K.

5. Plans for 2005

The first geodetic observation within the VERA network using 1Gbps recording system was successfully done in November, 2004. Internal precision of a few mm was achieved for horizontal positions. Details of the results will be reported elsewhere. Regular geodetic observations every two weeks are under way and will be continued throughout 2005. Geodetic observation has been passed to the 20m telescope and the use of the 10m antenna will be limited to backing up the observations for the GSI when the 20m telescope is not available. However, it is needless to say that it will be used for other purposes such as the phase calibration of the VERA system and tracking experiment of artificial satellites.

Noto Station Activity

G. Tuccari

Abstract

The most important achievements at the Noto station are presented and a general status is described about developments and future plans. In particular the progress related to the DBBC development, a digital base band converter system, is reported in some detail.

1. Station Activity and Upgrade

In 2004 the Noto antenna was widely used in numerous observation programs, including VLBI with EVN session, IVS session, Radar session, and single dish activity in spectroscopy and total power. The antenna activity is planned, including maintenance programs, with the help of a "time commission".

1.1. Receivers and Microwave Technology

The cooled multi-feed SXL receiver is now complete and ready to be mounted in the antenna receivers' environment. The introduction of this system requires an antenna stop because of the different installations it involves. Indeed it is composed of three sections: one in primary focus, one in secondary focus, and one in the control room. The sky frequency is transferred from the primary focus to the vertex room using low loss cables. Frequency conversion is performed in the secondary focus room. All the other receivers' IFs are routed through the same system to the control room, using fiber optic connections. So the system introduction affects also the other receiver bands, and a period of time of not less than one week is required for installation. Due to the introduction of a "full time" observing program, it was not possible until the beginning of 2005 to introduce such receiver and it was preferred not to observe the wide band geodetic experiment. During 2005 the receiver set will be done, but at present it is not possible to fix a date because it is related to the general antenna planning.

The 86 GHz receiver in Noto is still not operative for VLBI because of the necessity of a relative long period of pointing and calibration time. During 2005 more time slots are planned, but due to the closeness of the Noto antenna to the sea, the weather plays a very critical part.

The new VHF-UHF receiver, covering the range 250-600 MHz, and 600-1000 MHz was successfully used in EVN observations.

1.2. Acquisition Terminal and Digital Technology

The Mark 5A recorder is now the standard recording system in Noto and the tape recorder fell into disuse. A large number of disk packs has been acquired in 2004, and several more units are planned to be bought in 2005. The NRTV, a narrow band recording system, is used for RadarVLBI observations, connecting through the standard Internet network more stations with Noto, including Bear Lakes, Simeiz, Evpatoria, Urumqi.

The DBBC project for the realization of a digital base band converter system was fully operative and two prototypes were produced. In a parallel similar project, the "mDBBC", a collaboration between Noto and Shanghai radiotelescopes for the Chinese Lunar Program, fringes have been obtained with the digital system during 2004. At the end of 2004 a 16 channel prototype was under construction, planned to be ready in the summer of 2005, and to be used for testing the methodology as well as to serve as a basis for a possible mass production.

Several configurations have been developed including 0.5, 1, 2, 4 MHz bwd, to be improved, but is working; 0.25, 8, 16 MHz is near to completion; 0.125, 0.0625, 0.03125, 32 MHz is ready in simulation; tunable base band with 1 Hz resolution is ready today; tuning range in Nyquist blocks of 64 MHz is ready; tuning range in Nyquist blocks of 128 MHz is close to completion; tuning range in Nyquist blocks of 256, 512 MHz ready in simulation.

Good performance in conversion and tuning have been measured from 0 up to 2.5 GHz with selected AD converters (much more than expected). Today with an appropriate Nyquist zone pre-selection, L and S band can be directly down-converted and recorded with modified MK4 formatter (Noto and EVN spare).

Figure 1. DBBC Prototype

2. Geodetic Experiments in Noto during 2003

During 2004 the Noto radiotelescope participated in the following geodetic experiments: T2025 (JAN 13), CRF25 (JAN 26), T2027 (MAR 9), CRF26 (MAR 30), EURO71 (APR 6), T2028 (APR 13), T2029 (MAY 11), CRF29 (JUL 5), EURO72 (JUL 13), EURO73 (SEP 6), T2034 (OCT 5).

NYAL Ny-Ålesund 20 Metre Antenna

Leif Morten Tangen

Abstract

For the year 2004, the 20-meter VLBI antenna at the Geodetic Observatory, Ny-Ålesund has participated in VLBI experiments at the scheduled level, except for the period 23th of September to 10th of October, when the Observatory was down due to receiver problems. Maintenance and repair have been done. After mid June there was only one person at the station because of a general reduction in the Mapping Authority. The station is now a Mark 5 station only.

1. General Information

The Geodetic Observatory of the Norwegian Mapping Authority at 78.9 N and 11.87 W is located in Ny-Ålesund, in Kings Bay at the west side of the island of Spitsbergen, the biggest island in the Svalbard archipelago. In 2004, Ny-Ålesund was scheduled for 80 VLBI experiments within R4, R1, EURO, VLBA/RDV, RD, T2 and ICRF. After mid June there was only one person at the station and all experiments with tape or more than two modules in Mark 5 have been cancelled. 70 experiments were run during the year. In addition to the 20-meter VLBI antenna, the observatory has two GPS antennas in the IGS system and a Super Conducting Gravimeter is installed on the site. On the site, there is also a CHAMP GPS and a PRARE installation. There is also a SATREF (dGPS) installation at the station.

Figure 1. Ny-Ålesund 20 meter antenna

2. Component Description

The antenna is intended for geodetic use, and is designed for receiving in S- and X- band. The equipment is Mark 5. Station configuration file: ivscc.gsfc.nasa.gov/pub/config/ns/nyales.config. Ny-Ålesund is located so far north that it has daytime aurora in winter. The location of the antenna enables signal reception over the North Pole. (In 1998, Ny-Ålesund was the only antenna that could receive signals from the Mars Global Surveyor for 24 hours.)

3. Staff

Table 1. Staff related to the operation of the VLBI in Ny-Ålesund.

Hønefoss:	Section manager:	Rune I. Hanssen	
	Station responsible, Hønefoss:	Svein Rekkedal	
Ny-Ålesund:	Station commander:	Leif Morten Tangen / Helge Digre	
	Engineers:	Vidar Eggimann David Holland	until 13.05.2004
	Engineer:	Sune Elshaug	until 31.05.2004

David Holland is still on sick leave. After May 13 there was only one person at the station. All the experiments are done during the normal working hours of one person.

4. Current Status and Activities

Ny-Ålesund has participated in VLBI experiments at the scheduled level, except for the period 23th of September to 10th of October, when the Observatory was down due to receiver problems. There were some problems with inert gases, causing a cold head failure. Some experiments had to be run with warm receiver. The Super Conducting Gravimeter placed on the same fundament as IGS-GPS NYA1, has been running without any problems. This year, PRARE became more and more unstable and work intensive. It is now turned off.

Ny-Ålesund is Mark 5A only. Both the FS and Mark 5 are upgraded to the latest software versions.

The Ministry of Environment funds the Norwegian Mapping Authority (NMA). For 2004, there have been cutbacks again. As a part of the process of reducing costs, two of the employees did not receive new contracts when the old ones ended in spring. It looks like there will be no change in 2005 and the observatory will be run in a minimum mode.

5. Future Plans

Ny-Ålesund will continue to participate in the experiments the antenna is scheduled for. The SCG has to be refilled with liquid Helium each year, and the lift has to be re-certified every year. We will try to do as many experiments as possible with the people at the station. We have ordered a new FS computer that will be delivered in 2005.

German Antarctic Receiving Station (GARS) O'Higgins

Wolfgang Schlüter, Christian Plötz, Walter Schwarz, Reiner Wojdziak

Abstract

In 2004 the German Antarctic Receiving Station (GARS) in O'Higgins contributed to the IVS observing program with 10 observation sessions. Mark 5 system has been used. Remote Control Software and Hardware has been installed and successfully used.

1. General Information

The German Antarctic Receiving Station (GARS) is jointly operated by the Federal Office of Cartography and Geodesy (BKG), the German Aerospace Center (DLR) and the Institute for Antarctic Research Chile (INACH). The 9m radiotelescope at O'Higgins is used for geodetic VLBI and for Remote Sensing. The access to the station is organized campaign-wise during the Antarctic spring and summer. In 2004 the station was occupied from January to March and from October to December. DLR and BKG jointly send engineers and operators for the campaigns together with a team which maintains the infrastructure such as the provision of power etc. Special flights with "Hercules"-aircrafts and small TwinOtters-aircrafts were organized by INACH in close collaboration with the Chilean Army, Navy and Airforce in order to transport the staff, the technical material and also the food for the entire campaign from Punta Arenas via Island Frey to the station O'Higgins on the Antarctic Peninsula. Conditions and time schedule are unpredictable and requires a lot of security precautions. Arrival time and departure time is strongly dependent on the weather conditions and the general logistics.

After the long Antarctic winter usually the equipment at the station has to be initialized, damages, which result from the strong winter period, have to be identified and repaired. Shipment of spare parts or material for upgrades from Germany needs careful preparation in advance, nevertheless the arrival of material in O'Higgins is mostly delayed.

In collocation with the 9m Radiotelescope for VLBI

- two GPS receivers are operated all over the year, an Alan Osborn ACT (OHIG 2), which has a long and stable history and a JAVAD receiver (OHIG3), which was installed during the summer campaign 2004 replacing the previous Ashtech Z18 receiver for GPS and GLONASS tracking.
- a tide gauge is installed, which was operated several years with some interruptions caused by destroyed cables from the scratching ice on the rocks,
- a meteorological station providing pressure, temperature and humidity and wind information, as long as the extreme conditions outside did not disturb the sensors,
- an H-Maser, an Atomic Cs-clock, a GPS time receiver and a Total Accurate Clock (TAC) are employed for the provision of the time and frequency.

The 9m radiotelescope is designed for dual purposes: for performing geodetic VLBI and for receiving the remote sensing data from ERS 2, JERS and ENVISAT. Different antenna tracking modes and different receivers have to be activated depending on the application.

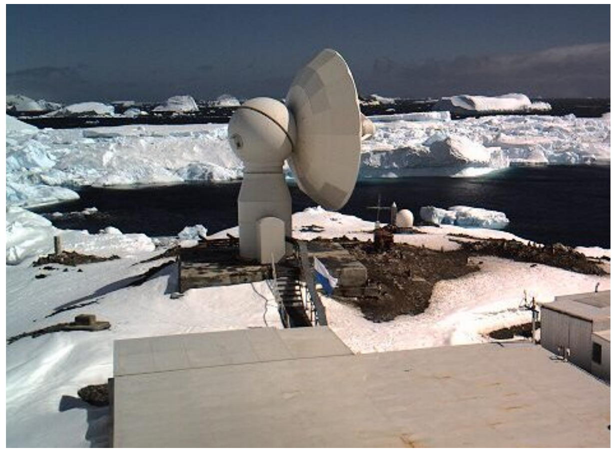

Figure 1. GARS O'Higgins

2. Technical Staff

The staff members for operating, maintaining and improving the GARS VLBI component and the geodetic devices are summarized in Table 1. The University of Concepción, which collaborates with BKG in the TIGO project, supported the observations at O'Higgins by sending an engineer for the term from October to December.

Table 1. Staff – members

Name	Affiliation	Function	Working for
Christian Plötz	BKG/FESG	electronic engineer	O'Higgins (responsible), RTW
Walter Schwarz	BKG	electronic engineer	RTW, O'Higgins
Reiner Wojdiak	BKG	software engineer	O'Higgins, IVS Data Center Leipzig
Cristobal Jara	UdeC	electronic engineer	TIGO, O'Higgins

3. Observations in 2004

During the Antarctic summer campaign (January-March 2004) and during the Antarctic spring campaign (October-December 2004) GARS participated in the following sessions of the IVS observing program:

- 4 sessions during the period January–February (OHIG29, OHIG30, OHIG31, and T2026)
- 6 sessions during the period October–December (OHIG32, OHIG33, OHIG34, OHIG35, T2035 and T2036)

The observations in January-February were stored on tapes while the observations during the second period were recorded on disks with Mark 5A. OHIG32 and OHIG33 were recorded on both data media, tapes and disks. The data were shipped from O'Higgins to Punta Arenas with the earliest possibility after they were recorded. They already are available for correlation. A pre-correlation did not indicate any technical problems and confirmed the successful operation of Mark 5A at O'Higgins.

4. Maintenance

The extreme conditions in the Antarctic require special maintenance and repair of the GARS telescope and of the infrastructure. We have to consider the effect of corrosion; problems with connectors and capacitors need to be detected; the H-Maser has to be set up into operation mode as soon as the operators arrive; the antenna, the S/X-band receiver and the data acquisition system have to be activated properly. Those components which were damaged during the previous campaign usually have to be replaced.

5. Technical Improvements

The transition from the Mark IV to the Mark 5A has been successfully performed. Data were already recorded since October 2004 with the Mark 5A.

A new computer has been prepared and modified for the implementation of the new Field System version 9.6.9. The Field System was adapted to the O'Higgins VLBI system and the observations were already run with the new version. An additional computer was implemented to monitor the H-Maser status. The Maser monitoring data are made available for remote control from Wettzell Observatory.

Remote control extensions have been set up, allowing access of the VLBI control system in O'Higgins from Wettzell. The observations T2036, carried out on December 7/8 and the observations OHIG 35, carried out on December 8/9 were completely operated from Wettzell. Due to the unpredictable transportation conditions to and from O'Higgins, the BKG staff had to leave on December 7. By using the remote control capability the observations were successfully performed. The remaining local work was taken over by DLR staff, as the shipment of the disk packages.

During the 1st campaign in February 2004, a new power generator with 120kVA including UPS was installed, replacing an old worn-out system that did not provide sufficient power for the increasing activities. The air conditioning in the operation containers was significantly improved by a complete replacement of the old devices. The temperature can now be kept stable within 2 degrees Kelvin in the operation rooms, which improved the overall stability of all electronic components.

All computers for operating the geodetic devices and all servers were replaced with the new PC generation. The 128kbps Internet link via satellite to Santiago was used for data transmission of the continuous observations such as GPS, tide gauges etc. during the year. The capacity allows the remote access, but a faster link with more capacity is strongly required.

6. Upgrade Plans for 2005

During 2005 it is planned to expand the observing capabilities in particular by extending the period of possible observations. This requires to improve the remote control capabilities and to increase the Internet capabilities by at least a factor of two (256kbps). The upgrade to Mark 5B is planned as soon as the devices or the upgrade kits are available.

Some restoration work will be done, in order to maintain the antenna as corrosion has to be prevented. It is also planned by DLR to replace the first Antenna Control Unit by the latest development of VERTEX.

The IVS Network Station Onsala Space Observatory

Rüdiger Haas, Gunnar Elgered

Abstract

We summarize briefly the status of the Onsala Space Observatory in its function as an IVS Network Station. The activities during the year 2004, the current status, and future plans are described.

1. Overview

Descriptions of the IVS Network Station at the Onsala Space Observatory (OSO) have been included in previous IVS annual reports, see e.g. [1] and references in there. In 2004 we started to use the 1 Gbps fiber link connection for eVLBI tests. The first ever intercontinental real-time VLBI fringes were obtained on the baseline Onsala–Westford. We organized a first NORDIC experiment including the available stations in Fennoscandia. Unfortunately, no fringes on baselines with Onsala were found in this experiment. One of the two masers at the observatory failed and was taken out of operation. Throughout the year 2004 we still experienced problems with the amplifiers of the telescope's azimuth encoders. In late November the cooling system of the S/X receiver failed and thus the last three experiments in 2004 had to be observed with a warm receiver.

2. Staff Associated with the IVS Network Station at Onsala

The staff associated with the IVS Network Station at Onsala remained mainly the same as reported in the IVS Annual Report 2003 [1].

Table 1. Staff associated with the IVS Network Station at Onsala. All e-mail addresses end with @oso.chalmers.se; the complete telephone numbers start with the prefix +46-31-772.

Function	Name	e-mail prefix	telephone extension
Responsible P.I.s	Rüdiger Haas	haas	5530
	Gunnar Elgered	kge	5565
Observatory director	Roy Booth	roy	5520
Ph.D. students and Postdoc involved in VLBI observation	Sten Bergstrand	sten	5566
	Camilla Granström	camilla	5566
	Martin Lidberg	lidberg	5578
	Tobias Nilsson	tobias	5575
	Borys Stoew	boris	5575
Field system responsibles	Biörn Nilsson	biorn	5557
	Michael Lindqvist	michael	5508
VLBI equipment responsibles	Karl-Åke Johansson	kaj	5571
	Leif Helldner	helldner	5576
VLBI operator	Roger Hammargren	roger	5551
Telescope scientists	Per Bergman	bergman	5552
	Lars Lundahl	lundahl	5559

3. Geodetic eVLBI Activities During 2004

The Onsala Space Observatory is connected to the Swedish Internet backbone via a 1 Gb/s optical fiber link since late 2003 [1]. This made it possible for us to carry out a number of eVLBI activities during 2004. Table 2 lists Onsala's eVLBI activities concerning the geodetic application of VLBI. The highlight is that the first ever successful intercontinental real-time eVLBI fringes were achieved on March 25, 2004, on the baseline between Onsala and Westford.

Table 2. Geodetic eVLBI activities at the Onsala Space Observatory during 2004.

February 27	Intensive network tests between Onsala and the Haystack correlator
March 25	Real-time eVLBI experiment Onsala–Westford at 32 Mbps, correlated at the Haystack correlator, first intercontinental real-time eVLBI fringes
April 26	Successful autocorrelation of Onsala data at the Haystack correlator at 64 Mbps
August 31	Failed eVLBI test Onsala–Westford at 256 and 128 Mbps
September 13	Failed eVLBI test Onsala–Westford
November 08	Real-time demonstration experiment at the SuperComputing 2004 conference, successful correlation of pre-recorded data from Onsala at the Haystack correlator a data rates higher than 200 Mbps [5]

4. Geodetic VLBI Observations During 2004

In 2004 the observatory was involved in the six VLBI-experiment series EUROPE, IVS-R1, IVS-R4, IVS-T2, RDV, and RD04. We volunteered to replace Matera in five IVS-R1 and IVS-R4 sessions in the second half of 2004. Furthermore, we organized a NORDIC session including all VLBI stations in northern Europe. In total, OSO participated in 29 geodetic VLBI experiments during 2004 (see Table 3). The six RDV sessions were recorded on tapes. All other experiments were recorded on Mark 5 disc modules.

5. Technical Problems of the Onsala VLBI System During 2004

Although new amplifiers for the telescope's azimuth encoders had already been installed in late 2003, the problem with the encoders continued in 2004. Unfortunately several experiments suffered considerable loss of observational data due to problems with the telescope's azimuth encoders during 2004 (see Table 3).

Radio interference in S-band due to UMTS mobile telephone signals continued to be a disturbing factor in 2004. Some correlation reports mentioned explicitly the radio interference.

The EFOS maser at Onsala failed in June 2004 and was switched off completely. A repair of this maser would have been too expensive and could not be afforded. The observatory's Kvarz maser continues to be connected to the VLBI system.

In late November the cooling system of the S/X receiver failed. A new cooling head had to be purchased and was installed at the end of the year. However, three complete experiments had to be observed with a warm receiver (see Table 3).

Table 3. Geodetic VLBI experiments at the Onsala Space Observatory during 2004.

Exper.	Date	Remarks (problems)	Exper.	Date	Remarks (problems)
R4.103	01.08	o.k.	R1.131	07.12	o.k.
T2.025	01.13	o.k.	EURO.72	07.13	o.k., encoder problems
R4.105	01.22	o.k.	RDV.45	07.14	o.k., encoder problems
NORD.01	03.01	no fringes with Onsala	R4.133	08.05	o.k., encoder problems
RDV.43	03.03	o.k.	RDV.46	08.25	o.k.
R4.111	03.04	o.k.	EURO.73	09.06	o.k., encoder problems
R4.113	03.18	o.k.	R1.139	09.07	o.k., encoder problems
RD.0401	03.24	no correlation report yet	R1.140	09.13	o.k., encoder problems
R4-115	04.01	o.k., encoder problems	T2.033	09.14	o.k.
EURO.71	04.06	o.k.	RDV.47	10.06	o.k.
RDV.44	05.05	o.k.	R4.149	11.23	o.k., but partly RX warm
RD.0403	05.12	o.k.	RDV.48	12.01	RX warm,not correlated yet
R4.121	05.13	o.k.	R4.151	12.09	o.k., but RX warm
R1.129	06.28	o.k.	EURO.74	12.14	RX warm, not correlated yet
R4.128	07.01	o.k.			

Table 4. Technical problems of the Onsala VLBI system during 2004.

Whole year	Sometimes failing amplifiers of the azimuth encoder motors
Whole year	RFI in S-band
June	EFOS maser failed and was taken out of operation
November	Cooling system of the S/X receiver failed, repaired in December

6. Telescope Stability, Local Tie, and Pressure Sensor Calibration

Also in 2004 we continued to monitor the vertical changes of the telescope tower by an invar monitoring system [1], [3]. The campaign based GPS measurements using an antenna mounted on top of the VLBI telescope [4] have been continued, too.

Throughout the year 2004, the calibration campaign for the Onsala pressure sensor was continued [1], using a reference barometer provided on a long term loan by the Swedish Meteorological and Hydrological Institute (SMHI). The pressure readings of the two sensors are highly correlated (Fig. 1a). The differences in pressure readings do not show a significant dependence on the magnitude of the pressure (Fig. 1b). However, a slight seasonal dependence of the differences in pressure readings is detected (Fig. 1c), with an amplitude of about 0.25 hPa.

7. Outlook and Future Plans

The Onsala Space Observatory will continue to be an IVS Network Station and to participate in the IVS observation series. For the year 2005 a total of 26 experiments in the series EUROPE, IVS-R1, IVS-T2, RDV, and RD05 are planned.

We plan to continue to participate in international eVLBI activities and hope to increase the number of eVLBI experiments.

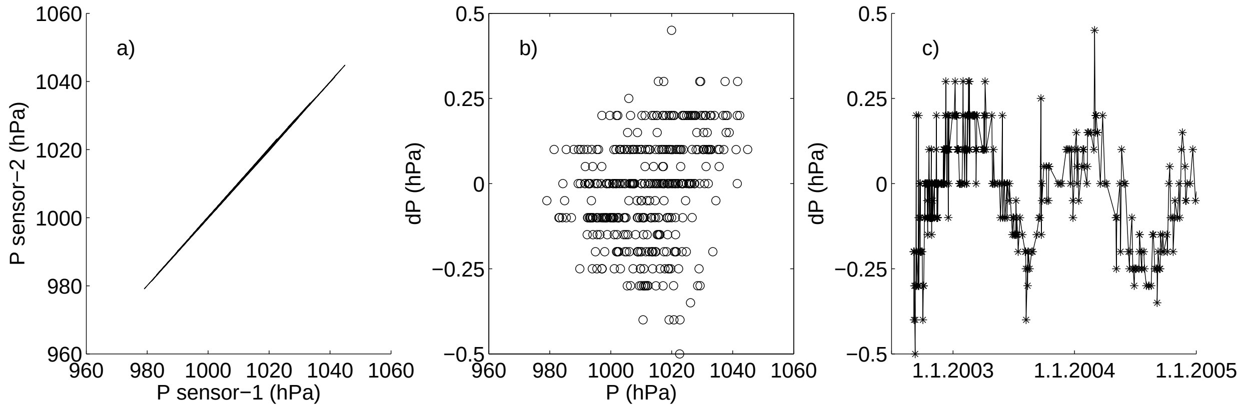

Figure 1. Results of the calibration campaign for the Onsala presssure sensor: a) Scatter plot of the pressure readings of the two sensors. b) Difference of pressure readings as a function of the pressure value. c) Time series of difference in pressure readings.

On the technical side, we will continue to work on the problem of the sometimes failing azimuth encoder amplifiers in order to reduce the loss of observational data.

The relevant VLBI system parameters will be monitored also in the future in order to detect possible error sources as early as possible and to maintain a high quality of the observational data. The stability of the telescope, its vertical height changes and the local tie to other monuments will be monitored also in the future.

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Sheshan VLBI Station Report for 2004

Xiaoyu Hong, Wenren Wei, Shiguang Liang, Xinyong Huang

Abstract

The Sheshan (also called Seshan) 25-meter radio telescope is an alt-az antenna run by Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS). It is one of the six main astronomical facilities of Chinese National Astronomical Observatories. The VLBI station is a member of the EVN, IVS, and APT. We give a short report about the current status and future plans of Sheshan VLBI station of Shanghai Astronomical Observatory as an IVS Network station.

1. Introduction

The telescope is located about 30 km west of Shanghai. Station located at longitude 121^o 11' 59" E, latitude 31^o 05' 57" N, and height 5 meters above sea level (ground).

The radio telescope started its operation in 1987. It is one of the five main astronomical facilities of Chinese National Astronomical Observatories. The VLBI station is a member of the EVN, APT and IVS. There is a two-station Mark IV data processor and an analysis center of IERS of various space geodetic observations in Shanghai Astronomical Observatory.

Sheshan station participates in the EVN sessions for astrophysics, IVS sessions and APSG observations for the geodetic purpose.

2. Facilities

2.1. Antenna

Diameter : 25 meters
Antenna type: Cassegrain beam wave-guide
Seat-rack type: Azimuth-pitching ring
Main surface precision: 0.65 mm (rms)
Point precision: 20"(rms)
Rolling range: Azimuth : $-86^o - 425^o$; Elevation: $5^o - 88^o$
Maximum rolling speed: Azimuth : 0.55^o/sec; Elevation: 0.28^o/sec

The control system of the telescope is being upgraded. We expect to have maximum rolling speed in azimuth (1.0^o/sec) and elevation (0.5^o/sec) after the upgrade.

2.2. Receiver

Five bands for VLBI observations are available at Sheshan VLBI station: L band (18 cm), C band (6 cm), K band (1.3 cm), and S/X band (13/3.6 cm). The parameters of the receivers are listed in Table 1. Column 1 gives the observation band. The frequency range is listed in column 2, followed by the efficiency of each band in column 3. The receiver type, system temperature, and polarization model are listed in columns 4, 5 and 6, respectively.

The L, C, and K bands are used for astrophysics and S/X double frequencies are used for geodesy. X band is also used for astrophysical observations sometimes.

A new C-band receiver with double polarizations has been used since Oct. 2004.

Table 1. VLBI Receivers of Seshan Station

Band (cm) (1)	**Bandwidth** (MHz) (2)	**Efficiency** (%) (3)	**Type** (4)	T_{system} (K) (5)	Polarization (6)
18	1620-1680	40	Room Temperature	$\sim$ 100	LCP & RCP
13	2150-2350	45	Room Temperature	$\sim$ 100	RCP
6	4700-5100	58	Cryogenic	$\sim$45-50	RCP &LCP
3.6	8200-9000	50	Cryogenic	$\sim$ 50	RCP
1.3	22100-22600	$\sim$20	Cryogenic	$\sim$110	RCP & LCP

2.3. Recording System

VLBA, Mark IV, Mark 5 and S2 recording systems are available now at Sheshan VLBI station. The performance of the observing system of Shanghai station has been more advanced over the last few years.

The Field System has been upgraded to 9.7.0 version and it worked well for Sheshan station in 2004.

The recording system has been upgraded to Mark 5A system in May 2004 and it works well for IVS and EVN observations. So the tape recorder has not been used then.

A new Hydrogen Maser MHM2010A has been installed and used since July 2004 and it works well.

2.4. Correlator

A new correlator with 5 stations is being built in Shanghai Astronomical Observatory. We expect to have our new correlator in 2006.

3. Personnel

There are some changes of the staff in Sheshan station. The main staff members at Sheshan VLBI Station are listed in Table 2.

Our senior engineer Xinyong Hunag retired in Oct. of 2004. She is still working with us after her retirement.

4. Current Status & Activities and Future Plans

The antenna control system will be finished in second half of 2005.

A new L band receiver with double polarization will be available in second half of 2005

A new S/X band receiver has been designed and it will be available by the end of 2005.

Table 2 - The main staff in Sheshan VLBI Station

Name	**Position**	**Working area**	**email address**
Xiaoyu Hong	Professor	Head of station	xhong@shao.ac.cn
Wenren Wei	Professor	Chief Engineer	wwr@shao.ac.cn
Shiguang Liang	Professor	Microware	sgliang@shao.ac.cn
Xinyong Huang	Senior Engineer	VLBI friend	xhuang@shao.ac.cn
Zhuhe Xue	Senior Engineer	Terminal software	zhxue@shao.ac.cn
Qingyuan Fan	Senior Engineer	Antenna control	qyfan@shao.ac.cn
Tao An	VLBI friend	Astrophysics	antao@shao.ac.cn
Songlin Chen	Engineer	Microware	slchen@shao.ac.cn
Bin Li	Engineer	Microware	bing@shao.ac.cn
Jinqing Wang	Engineer	Observation et al	jqwang@shao.ac.cn
Huihua Li	Engineer	Observation et al	hhlee@shao.ac.cn
Lingling Wang	Engineer	Observation et al	llwang@shao.ac.cn
Ruiming Tu	Engineer	Observation et al	trmshao@shao.ac.cn
Weihua Wang	Associate Research	Astrophysics	whwang@shao.ac.cn

10 Years of Geodetic Experiments at the Simeiz VLBI Station

A.E. Volvach

Abstract

This report gives an overview about the geodetic VLBI activities during 10 years at the Simeiz station. The positions of the points in the fundamental geodynamics area "Simeiz-Katsively" have been determined by special GPS survey campaign. It also summarizes the seasonal and long-term variability of the Black Sea level near Yalta and Katsively.

1. Introduction

The 22-m radiotelescope of the Crimean Astrophysical Observatory participated in the very first intercontinental very long baseline interferometric (VLBI) observations in September 1969 under astrophysical programs. The early narrow-band VLBI observations provided decameter accuracy and were not useful for geodynamics applications. The telescope was upgraded in 1994: a Mark IIIA data acquisition terminal and a dual-frequency horn were loaned from NASA/GSFC, dual band S/X receivers were supplied by the Institute of Applied Astronomy in Saint-Petersburg, Russia, a CH-70 hydrogen maser was supplied by the Institute of Space Research in Moscow. Interferometric fringes were obtained in the first test carried out on June 20, 1994. This upgrade enabled the station to join international observing campaigns under both astrophysical and geodynamics programs.

2. Measurements of Motion of Simeiz Station Using VLBI.

All available dual-band geodetic Mark III VLBI observations for 21 years, from 1979.59 till 2000.72 were used in the analysis: 3 058 sessions, **3 005 651** observations including 36 successful sessions with participation of the station Simeiz for 6 years: 1994.48–2000.36 with **19 631** good measurements of group delays.

Estimates of the horizontal velocity of the station Simeiz were calculated using VLBI observations carried out under geodynamics programs during the years 1994-2000. The complete set of 3 million VLBI observations has been analyzed and it was found that the station moves with respect to the Eurasian tectonic plate considered as rigid with a rate of 2.8 ± 0.9 mm/yr in a North-North-East direction. Results are presented in Table 1 (azimuth is measured from North). The details of the analysis are stated in the paper of Petrov et al., 2001.

Estimates of the velocity of the radioastronomical station Simeiz were obtained using VLBI observations carried out under geodynamics programs during the years 1994-2004 using Occam 5.1 for data analysis (Volvach, Sokolova, Shabalina, 2004). Figure 1 show the time series of topocentric coordinates of Simeiz.

3. The Fundamental Geodynamics Area "Simeiz-Katsively"

The fundamental geodynamics area "Simeiz-Katsively" is situated on the coast of the Black Sea near the village of Simeiz 20 km west of the city of Yalta in Ukraine. It consists of two satellite

Table 1. Residual station velocities with respect to the Eurasian plate.

Station	Up (mm/yr)	East (mm/yr)	North (mm/yr)	Corr E-N	Hor. Rate (mm/yr)	Azimuth Deg	D
DSS65	2.1 ± 1.5	-0.1 ± 0.2	0.0 ± 0.1	0.86	0.1 ± 0.2	271±51	h
EFLSBERG	-0.5 ± 0.8	0.5 ± 0.3	-0.4 ± 0.2	0.03	0.7 ± 0.2	132±22	h
MATERA	1.1 ± 0.9	0.9 ± 0.4	4.9 ± 0.4	0.30	5.0 ± 0.5	11±5	f
MEDICINA	-3.1 ± 0.8	1.7 ± 0.4	2.0 ± 0.4	0.11	2.6 ± 0.4	40±8	f
NOTO	0.6 ± 1.0	-1.0 ± 0.5	5.0 ± 0.4	0.30	5.1 ± 0.4	349±6	f
NYALES20	5.8 ± 1.5	0.0 ± 0.0	0.0 ± 0.0	-0.92	0.0 ± 0.0	350±65	h
ONSALA60	3.3 ± 0.6	-1.0 ± 0.4	-0.8 ± 0.4	-0.11	1.3 ± 0.3	229 ± 17	f
WETTZELL	-0.0 ± 0.1	-0.3 ± 0.2	0.4 ± 0.2	-0.04	0.5 ± 0.2	322± 25	hv
SIMEIZ	2.7 ± 3.0	1.3 ± 0.7	2.5 ± 0.9	**0.07**	**2.8 ± 0.9**	**27 ± 15**	f

The last column contains status of the station: free (f), defining for horizontal motion (h), defining for both horizontal and vertical motion (hv).

laser ranging stations, a permanent GPS receiver, a sea level gauge and the radiotelescope RT-22. All these components are located within 3 km (Figure 2).

The reference point of the antenna is the point of projection of the azimuthal axis onto the elevation axis. The coordinates of this point are determined in analysis of the observations. However, this point may move with respect to the local area where the radiotelescope is located.

Positions of both horizontal and azimuthal axis were also carefully measured with precision of $2''$ during a special first GPS survey campaign in 1995 (Bolotin et al., 1995). One of the conclusions of the surveying campaign was that *“a more detailed study of the complete dataset gives us grounds to believe that the azimuthal axis draws a cone in space and has smooth random wobbles when the antenna moves on azimuth. Nevertheless, the total effect does not exceed ±1 mm”*.

The time series of the deviation of the azimuthal axis with respect to the local plumb line as a function of time is presented in the paper by Petrov et.al., 2001. The inclination angle is increasing with a rate $2''\!.6$ per year in the direction of azimuth 296 deg and we believe that the antenna is leaning like the Pisa tower.

The positions of the points in the geodynamics test area “Simeiz-Katsively” have been determined by special second GPS survey campaign by the Main Astronomical Observatory in October 2001 and third GPS survey campaign in August 2004. Results are presented in Table 2.

4. The Black Sea Level.

The 22-m radiotelescope RT-22 is located 80 m from the edge of the Black Sea. Yalta level gauge is located near Yalta 20 km east of RT-22. The level varied insignificantly from January to March. Then its prompt growth till May begins. Then the growth is slowed down and in June there comes a maximum. After July there is a fast fall up to the minimal size observable in October. Since October till November the seasonal level varies poorly. In the period since November till December the fast growth of a level which is slowed down in the period December - January is again observed.

The analysis of sea level changes of the Black Sea is carried out depending on solar activity and

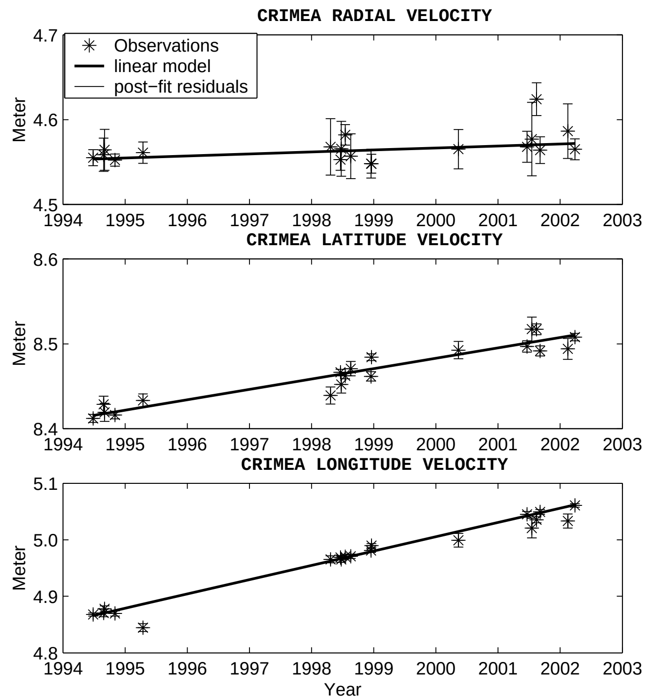

Figure 1. Crimea velocities: radial (top), latitude (middle) and longitude (bottom).

Table 2. Final solution for coordinates of points in the area “Simeiz-Katsively”.

Station	X, m	RMS, m	Y, m	RMS, m	Z, m	RMS, m
KTHI	3785378.6041	0.0004	2551165.3915	0.0003	4439717.4172	0.0004
KTLR	3785923.9017	0.0005	2550781.8054	0.0003	4439471.6117	0.0004
KTRT	3785160.8761	0.0004	2551262.2573	0.0002	4439789.8357	0.0004
SIME	3783746.4067	0.0000	2551362.7445	0.0000	4441445.1801	0.0000
CRAO	3783897.2187	0.0006	2551404.3953	0.0004	4441264.2859	0.0006
SIMI	3783887.4552	0.0004	2551403.5454	0.0003	4441266.8603	0.0005
KTE2	3785236.0690	0.0477	2551188.5462	0.0308	4439784.2244	0.0531
KTE1	3785206.0519	0.0345	2551216.1368	0.0240	4439790.8836	0.0426

geophysical conditions using the data of monthly observations of a level of the Black Sea in item. Katsively for the period from 1992 to 2004. The data cover the period of a phase of recession 22 and 23 cycles of solar activity. The long data of measurements of a sea level allow to look for possible influences of solar activity and geophysical conditions on observable changes of the sea level. The long-term changes are shown as regular trend as constant increase of a sea level from 1992 up to 2000, with gradual recession by 2004. The short-term changes are shown as seasonal variations of increase of a sea level from January to middle of the year and their subsequent recession by the end of the year. The amplitude of seasonal variations also varies from year to year. Such character of change of a level of the Black Sea allows to assume an opportunity of joint influence on a sea

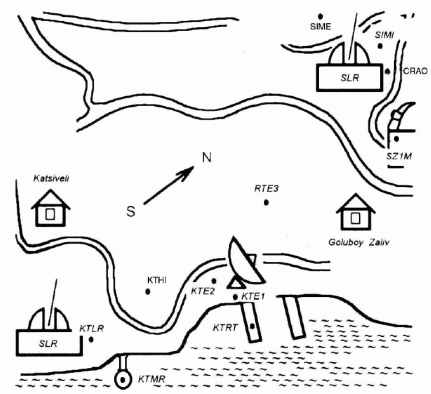

Figure 2. The geodynamics area “Simeiz-Katsively”.

level of the most various factors connected with solar activity and geophysical conditions during realization of measurements.

5. Future Plans

The VLBI activities in 2005 at “Simeiz-Katsively” area will consist of: (1) carrying out modernization of sites VLBI (Mark 5B system), SLR-1 and SLR-2 with the purpose to increase their level of equipment according to the international standards; (2) realization of observations on sites VLBI and SLR for maintenance in territory of Crimea the International Terrestrial Reference Frame (ITRF) and high-precision connection (at a level of several millimeters) permanent GPS stations of the network to ITRF; (3) creation of the prototype of a system of monitoring of geodynamic phenomena of mountain region of Crimea and geotectonic of the Black Sea basin.

6. Acknowledgment

VLBI is possible only as a result of the coordinated efforts of many people. The authors would like to thank I. Srepka and N. Srepka for maintenance of the receivers at the station, P. Nikitin, A. Shevchenko and P. Koseko for their efforts in observations as well as the personnel at other VLBI stations and correlators.

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Svetloe Radio Astronomical Observatory

Sergey Smolentsev, Ismail Rachimov

Abstract

This report provides information about changes in the Svetloe Radio Astronomy Observatory (SvRAO) status in period spanning after the last IVS report. The activities during 2004, the current status, and future plans are described. During 2004 a number of maintenance and upgrade activities were performed at SvRAO. Mark 5A and S2-DAS are available at SvRAO for IVS programs.

1. Introduction

Svetloe Radio Astronomical Observatory (SvRAO) was founded by the Institute of Applied Astronomy (IAA) as the first station of Russian VLBI network QUASAR. VLBI network QUASAR has been described in [1]. The second station of network QUASAR "Zelenchukskaya" has been accepted as an IVS Network Station by the IVS Directing Board, at its meeting on October 8, 2004.

Sponsoring organization of the project is Russian Academy of Sciences. SvRAO is located at the Karelian Neck near Svetloe village about 100 km north from St. Petersburg. The basic instruments of the observatory are 32-m radio telescope RTF-32 and technical systems provided realization of VLBI observations.

During last year Svetloe observatory regularly participated in various radio astronomy programs including VLBI and single dish observations of quasars, Sun and planets.

2. Participation in IVS Observing Programs

Table 1 summarizes the sessions performed during 2004.

Table 1. The list of IVS sessions observed at SvRAO in 2004.

Month	IVS-R4	IVS-T2	EUROPE	IVS-E3	NORD	Intensives
January	1	1				
February	2					
March	2				1	
April	3		1			
May	2	1		1		
June	2	1		1		
July	2	1	1	1		
August	3	1		1		
September	5	1	1	1		
October	2	1		1		
November	2	1		1		5
December	2	1	1	1		6
Total	28	9	4	8	1	11

Figure 1. Upgraded control room of the radio telescope after installation of Mark 5 and S2-DAS systems.

3. Collocation with GPS

Figure 2. GPS receiver Trimble 4000SST was replaced with Leica SR520 with choke ring antenna LEIAT 504 on Dec 1, 2004.

4. Outlook

Our plans for the coming year are the following.

- To put into operation the optical fiber link for remote control.
- Participation in 63 IVS R4, R1, T2, EURO and E3 observing sessions.
- Geodetic survey for accurate tie between the radio telescope and the SVTL GPS marker.

References

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JARE Syowa Station 11-m Antenna, Antarctica

Kazuo Shibuya, Koichiro Doi

Abstract

The operation of the 11 m S/X-band antenna at Syowa Station (69.0°S, 39.6°E) by the Japanese Antarctic Research Expeditions (JAREs) started in February 1998 and continues till today (February 2005). The number of quasi-regular geodetic VLBI experiments attained 57 at the end of 2004. We summarize the status of the experiments. We replaced the K4 back-end terminal with a K5 terminal. Fringe detection test was made on September 9, 2004, with the 32-m GSI/Tsukuba antenna. It was proved successful after Intelsat transfer of data (about 200 MB) from Syowa Station to GSI/Tsukuba and correlated there. The antenna time drastically decreased as receiving activity of remote sensing satellites became very low. We will increase, with the help of the observing program committee, the OHIG and CRF sessions than those planned in the 2005 year schedule (eight 24hr sessions).

1. Overview

Syowa Station has become one of the key observatories in the southern hemisphere geodetic network, as reported in [1]. As for VLBI, Syowa antenna is registered 66006S004 as the IERS Domes Number, and 7342 as the CDP Number. Basic configuration of the Syowa VLBI front-end system did not change from the description in [2]. In November 2003, JARE-45 brought down a K5 recording terminal (Figure 1) to replace the K4 terminal. The fringe detection test was made by using radio-source 1921-293 between Syowa and Tsukuba (GSI 34-m antenna). Data transfer rate of 0.5 - 1 Mbps by Intelsat transponder link assisted easy correlation. The test was found successful; this can be repeated for future maintenance. The Syowa experiments consisted of two sessions, SYW and OHIG from 1999 through 2004.

2. Notes on System Maintenance

There is no significant problem in the "mechanical system". The hydrogen maser set (Anritsu RH401A; 1001C), which was in good condition until 2003 was brought back to Japan for overhaul (H2 ran out). The 1002C is to be used for the 2004 and 2005 year observations until JARE-46 installs again 1001C to Syowa (planned January 2006). The tube in the Cs frequency comparator has to be changed, and the down-converter/local oscillator has to be replaced with a new one in the near future.

3. Session Status

Table 1 summarizes status of processing as of January 2005. The SYW session consists of Syowa (Sy), Hobart (Ho) and HartRAO (Hh). The OHIG session has involved Fortaleza (Ft), O'Higgins (Oh) and Kokee Park (Kk) with TIGO Concepcion (Tc) from November 2002, together with the SYW 3 antennas. In 2005, we will terminate SYW sessions. Instead, 2 CRF sessions are added to 6 OHIG sessions. We are going to test the capability of data transfer for a short-term (1h, 2h) experiment.

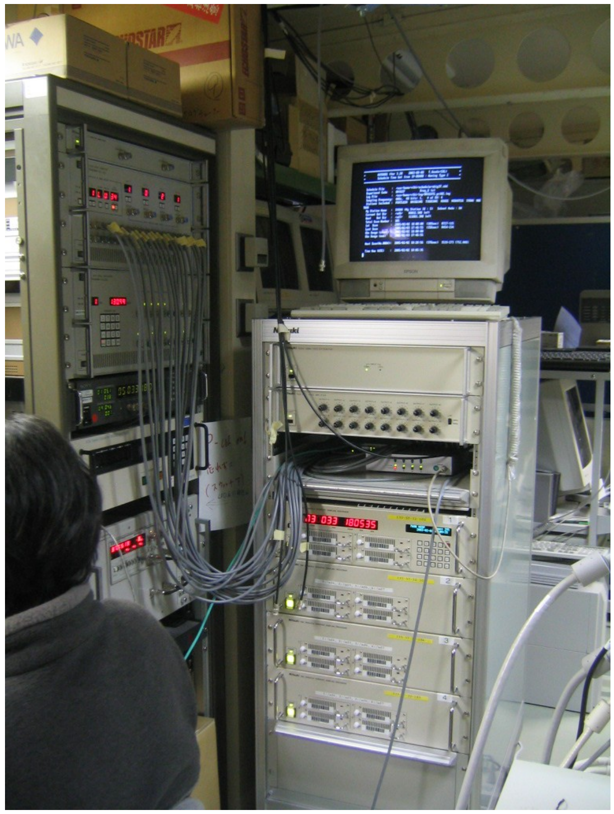

Figure 1. Hard Disk based 16 ch (4 ch x 4) data storage enabled us easy handling of recorded VLBI data.

4. Staff of the JARE Syowa Station 11-m antenna

- Kazuo Shibuya, Project coordinator at NIPR.
- Koichiro Doi, Liaison officer at NIPR.
- Hiroshi Ikeda (from Tsukuba University), Chief operator for JARE-44 (Feb. 2003 - Jan. 2004).
- Hirozaku Soeda (from NEC), Antenna engineer for JARE-44.
- Koichiro Doi (from NIPR), Chief operator for JARE-45 (Feb. 2004 - Jan. 2005).
- Kazuo Fukuhara (from NEC), Antenna engineer for JARE-45.

5. Analysis Results

Until the end of 2004, 37 sessions from May 1999 to February 2004 have been analyzed with the software CALC/SOLVE developed by NASA/GSFC. The data tapes of 10 sessions by JARE-45 (7 OHIG and 3 SYW) are not returned yet. The length of the Syowa-Hobart baseline is increasing with a rate of 55.04 ± 0.98 mm/yr. The Syowa-HartRAO baseline shows slight increase with a rate of 11.10 ± 0.82 mm/yr. These results agree approximately with those of GPS. We cannot find yet obvious change in the Syowa-O'Higgins baseline. The coordinates of Syowa VLBI ARP were determined with an error of 1.1 mm for the X component, 0.9 mm for the Y component and 2.4 mm for the Z component, respectively. These errors are 10 times smaller (better) than those in the IERS2000 Bulletin.

Table 1. Status of SYW and OHIG experiments as of January 2005

Code	Date	Station	Hour	Correlation	Solution	Notes
JA981	1998/Feb/09	Ho, Hh, Ka	48 h	S only	No	(J39)
JA982	1998/May/11	Ho, Hh, Ka	48 h	partial	No	
JA983	1998/Aug/09	Ho, Hh	48 h	No	No	
JA984	1998/Nov/09	Ho, Hh, Pa	48 h	Yes	Yes	(1)
CRF07	1999/Feb/15	Ho, Hh, Ft, Kb, Wz	24 h	No	No	(J40)
SYW991	1999/Feb/17	Ka	24 h	Yes	Yes	
COHIG6	1999/Feb/18	Ho, Hh, Ft, Kk	24 h	No	No	
SYW992	1999/May/13	Ho, Hh	24 h	Yes	Yes	
SYW993	1999/Jul/15	Ho, Hh	24 h	Yes	Yes	
SYW994	1999/Aug/26	Ho, Hh	24 h	Yes	Yes	
SYW995	1999/Sep/09	Ho, Hh	24 h	Yes	Yes	
SYW996	1999/Oct/07	Ho, Hh	24 h	Yes	Yes	
COHIG7	1999/Nov/08	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
COHIG8	1999/Nov/10	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
COHIG9	1999/Nov/11	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
SYW997	1999/Nov/18	Ho, Hh	24 h	Yes	Yes	
SYW008	2000/Feb/02	Ho, Hh	24 h	Yes	Yes	(J41)
COHG12	2000/Feb/10	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
SYW009	2000/Mar/20	Ho, Hh	24 h	Yes	Yes	
SYW010	2000/Jul/03	Ho, Hh	24 h	Yes	Hh-Ho only	(Syf)
SYW011	2000/Aug/08	Ho, Hh	24 h	Yes	Yes	
SYW012	2000/Sep/11	Ho, Hh	24 h	Yes	Yes	
SYW013	2000/Oct/05	Ho, Hh	24 h	Yes	Yes	
COHG13	2000/Oct/09	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
SYW014	2000/Nov/20	Ho, Hh	24 h	Yes	Yes	
SYW015	2000/Dec/07	Ho, Hh	24 h	Yes	Yes	
SYW016	2001/Feb/07	Ho, Hh	24 h	Yes	Sy-Ho only	(Hhf)
COHG14	2001/Feb/14	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	(J42)
COHG15	2001/Feb/19	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	
SYW017	2001/Apr/23	Ho, Hh	24 h	No	No	(Stf)
SYW018	2001/Jul/30	Ho, Hh	24 h	Yes	Sy-Hh only	(Hof)

Code	Date	Station	Hour	Correlation	Solution	Notes
SYW019	2001/Oct/04	Ho, Hh	24 h	Yes	Sy-Hh only	(Hof)
SYW020	2001/Nov/14	Ho, Hh	24 h	Yes	Yes	
COHG16	2001/Nov/26	Hh, Ft, Kk	24 h	Yes	Yes	
SYW021	2002/Jan/16	Ho, Hh	24 h	Yes	Yes	
OHIG19	2002/Feb/11	Ho, Hh, Ft, Oh, Kk	24 h	Yes	Yes	(J43)
SYW022	2002/Apr/29	Ho, Hh	24 h	Yes	Yes	
SYW023	2002/Aug/12	Ho, Hh	24 h	Yes	Yes	
SYW024	2002/Nov/04	Ho, Hh	24 h	Yes	Yes	
OHIG20	2002/Nov/12	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
OHIG22	2002/Nov/20	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Yes	Yes	
SYW025	2003/Jan/16	Ho, Hh	24 h	Not yet	Not yet	
OHIG23	2003/Jan/20	Ho, Hh, Ft, Oh, Tc	24 h	Yes	Yes	
SYW026	2003/Apr/10	Ho, Hh	24 h	Yes	Yes	(J44)
SYW027	2003/Aug/06	Ho, Hh	24 h	Yes	Yes	
OHIG27	2003/Nov/19	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
SYW028	2003/Nov/26	Ho, Hh	24 h	Not yet	Not yet	
OHIG28	2003/Dec/03	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
SYW029	2004/Jan/07	Ho, Hh	24 h	Yes	Yes	
OHIG29	2004/Feb/10	Ho, Hh, Ft, Oh, Tc	24 h	Yes	Yes	(J45)
SYW030	2004/Apr/07	Ho, Hh	24 h	Not yet	Not yet	
SYW031	2004/Aug/18	Ho, Hh	24 h	Not yet	Not yet	
OHIG32	2004/Oct/16	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG33	2004/Nov/09	Ho, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG34	2004/Nov/30	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
OHIG35	2004/Dec/08	Ho, Hh, Ft, Oh, Kk, Tc	24 h	Not yet	Not yet	
SYW032	2004/Dec/13	Ho, Hh	24 h	Not yet	Not yet	
OHIG36	2005/Jan/26	Ho, Hh, Ft, Oh, Kk	24 h	Not yet	Not yet	
OHIG37	2005/Feb/02	Ho, Hh, Ft, Oh, Kk	24 h	Not yet	Not yet	
OHIG38	2005/Feb/15	Ho, Hh, Ft, Oh, Kk	24 h	Not yet	Not yet	

(1) Pa: Parkes Ka: Kashima (Stf) S tape failed (Hhf) Hh failed (Hof) Ho failed (Syf) Sy failed
(J39) JARE-39: op T. Jike eng T. Tanaka
(J40) JARE-40: op Y. Fukuzaki eng. T. Ino (J41) JARE-41: op K. Doi eng S. Takao
(J42) JARE-42: op S. Iwano eng. Y. Tamura (J43) JARE-43: op K. Sakura eng M. Abe
(J44) JARE-44: op H. Ikeda eng. K. Soeda (J45) JARE-45: op K. Doi eng K. Fukuhara

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[1] Shibuya, K., Doi, K. and Aoki, S. (2003): Ten years' progress of Syowa Station, Antarctica, as a global geodesy network site. Polar Geoscience, 16, 29-52.

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Geodetic Observatory TIGO in Concepción

Hayo Hase, Armin Böer, Stefan Riepl, Sergio Sobarzo, Cristobal Jara, Roberto Aedo, Gonzalo Remedi, Marcus Moreno, Gonzalo Hermosilla

Abstract

During TIGO's third year of operation in Concepción, TIGO performed 96 24h VLBI-observations and is hence one of the most scheduled IVS-sites. The radiotelescope got a new antenna control unit. TIGO supported the operation at O'Higgins. Activities of the VLBI-group at TIGO during 2004 and an outlook for 2005 are given.

1. General Information

At the end of 2004 according to the bilateral agreement between Germany and Chile the initial period of 3 years of cooperation between

- Bundesamt für Kartographie und Geodäsie
- Universidad de Concepción
- Universidad del Bío Bío
- Universidad Católica de la Santísima Concepción
- Instituto Geográfico Militar

for the operation of the Geodetic Observatory TIGO in Concepción ended successfully. On March 10, 2004, the Directing Board of TIGO decided to renew the three years period of cooperation until the end of 2007. This will guarantee the continuation of the commitments of TIGO in the International Services throughout the period.

2. Component Description

The IVS-network station TIGOCONC is the VLBI-part of the Geodetic Observatory TIGO, which was designed to be a fundamental station for geodesy. Hence the VLBI-radiotelescope is collocated with an SLR-telescope (ILRS-site), a GPS/Glonass permanent receiver (IGS-site) and other instruments like water-vapour-radiometer, superconducting gravity meter, seismometer.

The atomic clock ensemble of TIGO consists of 2 hydrogen masers, 2 cesium clocks and 3 GPS-time receivers realizing the Chilean contribution to the Universal Time scale (Circular T, BIPM).

During September 2004 the radiotelescope operation at TIGO was paused for a replacement of the antenna control unit. The motivation for the ACU replacement was the fact that spare parts for the system designed 12 years ago became more and more difficult to get, as production lines of key components like microprocessors and motors had terminated. The replacement of the servo system included also the development of new control software. The replacement was executed successfully within only three weeks (to minimize downtime) by the contracted MAN Technology company, which was also responsible for the new design. The new design replaced seven former microprocessors by just one with better performance. Communications between host

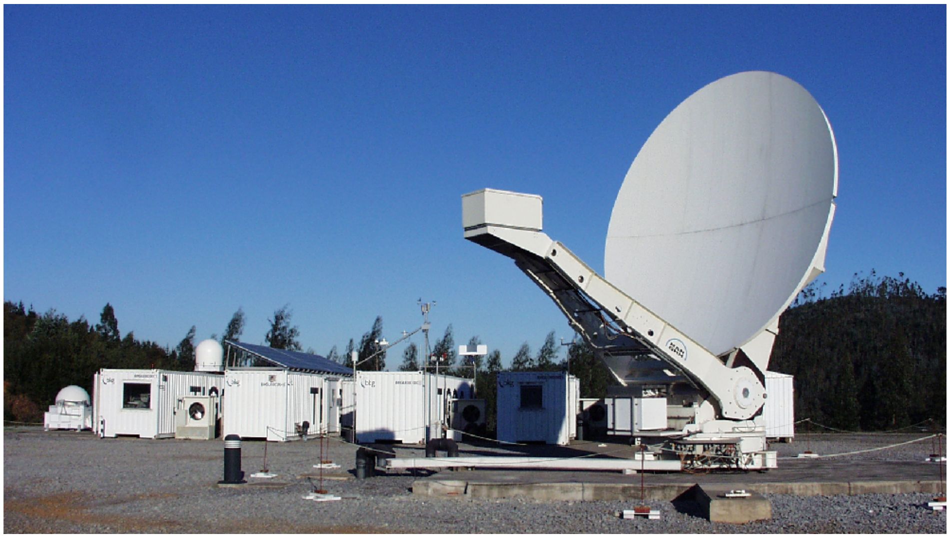

Figure 1. Geodetic Observatory TIGO: The VLBI-radiotelescope is the largest instrument of TIGO. Left in the back is the collocated SLR-telescope.

and remote computer are now realized by ethernet links, which permit higher data rates than the former serial connection. The new ACU is a digital system which permits profound diagnosis remotely and remote software updates via internet, while the radiotelescope is operating. The antenna controller time base is now derived from its own GPS receiver card replacing the time interface to the outside world in the former ACU. The new antenna controller routine for the Field System could be developed by TIGO staff prior to the replacement thanks to a simulator of the new ACU provided by MAN.

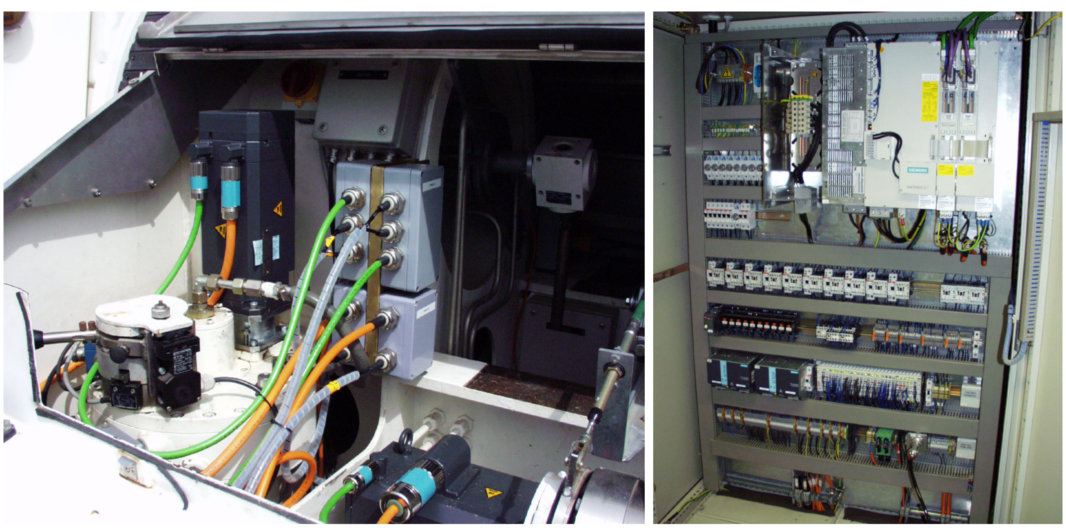

Figure 2. ACU replacement: New Siemens motors with new wiring had to be installed at the radiotelescope. The new switchboard cabinet shows its new Siemens servo and Beckhoff Profibus components.

3. Staff

In 2004 the TIGO VLBI group supported for first time the operation of the German Antarctic Receiving Facilities (GARS) at O'Higgins. After his training in VLBI operation at TIGO Cristobal Jara joined Christian Plötz from Wettzell in his campaign during October until December 2004.

The actual TIGO-VLBI group consists of the persons listed in Table 1.

Staff	Function	Email
Hayo Hase	head	hayo.hase@tigo.cl
Sergio Sobarzo	chief engineer	sergio.sobarzo@tigo.cl
Cristobal Jara	electronic engineer	cristobal.jara@tigo.cl
Roberto Aedo	electronic engineer	roberto.aedo@tigo.cl
Gonzalo Remedi	programmer	gonzalo.remedi@tigo.cl
Marcos Moreno (until Aug 04)	geologist	marcos.moreno@tigo.cl
Gonzalo Hermosilla (until Aug 04)	geologist	gonzalo.hermosilla@tigo.cl
Carlos Verdugo (since Jan 05)	mechanical engineer	carlos.verdugo@tigo.cl
any VLBI-operator	on duty	vlbi@tigo.cl
all VLBI-operators		vlbistaff@tigo.cl

Table 1. TIGO-VLBI support staff in 2004.

4. Current Status and Activities

During 2004 TIGO was scheduled for 97 VLBI-experiments (24h).

Name	# of exp.	ok	failed
R1xxx	42	42	-
T20xx	8	8	-
E30xx	11	11	-
R4xxx	26	25	1
RDVxx	3	3	-
OHIGxx	7	7	-
Total IVS	97	96	1

Table 2. TIGO's IVS observation statistic for 2004. In September 2004 TIGO was down for about 4 weeks due to ACU replacement.

In May 2004 Hayo Hase and Sergio Sobarzo presented together with Alan Whitney and David Lapsley the eVLBI subject at the national conference on communication networks for science, research and education. Previously TIGO conducted some data transmissions to Haystack and Bonn based on Mark 5 technology as feasibility study for future developments. It turned out that the infrastructure to and from Chile is worse than inside the country. This has to do with the long intercontinental distances.

TIGO is installing a regional GPS network. Since September 2004 the first GPS permanent station at Punto Faro Hualpen in about 15km distance westwards from TIGO is operational. A monument in Dichato (about 45km north) was constructed and will be equipped with permanent GPS, sea level tide gauge and meteorological station in early 2005.

5. Future Plans

The VLBI-activities in 2005 will focus on

- execution of the IVS observation program for 2005,
- participation at the IVS-TOW meeting in May,
- investigations related to eVLBI,
- fund allocation for eVLBI to get more bandwidth,
- general radiotelescope maintenance,
- experimental satellite trackings,
- repetition of the local survey.

Tsukuba 32-m VLBI Station

Junichi Fujisaku, Shinobu Kurihara, Kazuhiro Takashima

Abstract

This report summarizes the observation activities at the Tsukuba 32-m VLBI station by the Geographical Survey Institute (GSI) VLBI group. In 2004, the station had 36 international, 12 domestic and 60 intensive UT1 sessions. Some of these experiments, such as IVS-R&D and several UT1 sessions, were carried out using the disk-based K-5 sampling/recording system with internet data transfer. We plan to use this system for most of our sessions in 2005.

1. General Information

The Tsukuba 32-m VLBI station (TSUKUB32) is located at GSI in Tsukuba Science City, a core area of public and private scientific research institutes, about 50 km northeast of the capital Tokyo. GSI started VLBI experiments in 1981 with a 5-m mobile station and expanded its activities with a 3.8-m mobil station and the Kashima 26-m station.

Table 1. Location and address of Tsukuba 32-m VLBI station

Latitude (deg)	36.1031 N
Longitude (deg)	140.0887 E
Altitude	44.7 m
Address	Geographical Survey Institute(Kitasato 1 Tsukuba Ibaraki 305-0811 JAPAN)
Web	http://vldb.gsi.go.jp/sokuchi/vlbi/english/


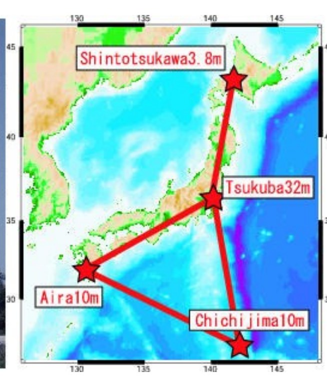

Figure 1. Tskuba 32-m VLBI station and GARNET (GSI VLBI network)

TSUKUB32 began operation in 1998. With this as a turning point, GSI shifted its aim for the experiments from the existing mobile observations to fixed regular ones. TSUKUB32 has been operating as a main dish of GSI with three other permanent VLBI stations, AIRA, SINTOTU3 and CHICHI10, performing geodetic VLBI experiments on a regular basis in a variety of international, domestic and other scientific experiments (Table 4). These four stations owned and run by GSI form a network named GARNET. The main purposes of GARNET are to define the framework of Japan and to monitor the plate motions for the advanced study of crustal deformations. For this reason the GARNET stations, centered on TSUKUB32, are placed to surround the Japanese mainland (Figure 1).

2. Component Description

The current configuration of TSUKUB32 is shown in Table 2. In 2004, we have made some improvements to our system. The Field System version we are currently using is FS-9.7.4. Field System has been installed in each of the three other GARNET stations for the first time, and now can carry out remote-controlled observations using Field System as well as TSUKUB32.

Table 2. Configuration of Tsukuba 32m antenna

Site 8-letter code	TSUKUB32	2-letter	Ts
IERS DOMES number	21730S007	CDP number	7345
X band SEFD (Jy)	320	S band SEFD (Jy)	360
X band Tsys (K)	50 (Zenith)	S band Tsys (K)	75 (Zenith)
Az slew 3.0 deg/sec	Range 10.0 - 710.0	El slew 3.0 deg/sec	Range 5.0 - 88.0
S-band w/BPF	2215-2369 MHz	X1-band	7780-8280 MHz
X2-band	8180-8680 MHz	X3-band	8580-8980 MHz

3. Staff

The regular operating staff of the GSI VLBI group are listed in Table 3.

Table 3. Staff working at GSI VLBI group

Name	Position	Jobs
Kazuhiro TAKASHIMA	Leader of VLBI group	Management
Morito MACHIDA	Analysis chief	Correlation, Operation
Masayoshi ISHIMOTO	Network chief	Network, e-VLBI, Operation
Junichi FUJISAKU	Operation chief	Experiments coordination, Operation
Shinobu KURIHARA	Operator	Analysis, Operation
Daisuke TANIMOTO	Visiting researcher	e-VLBI, Field System, Operation

In April 2004, three members left our group: Hiromichi Tsuji (Supervisor of VLBI group), Kozin Wada (Operation chief) and Takashi Tsutsumi (Collocation chief). Three new members joined our group: Satoshi Fujiwara (Supervisor of VLBI group), Junichi Fujisaku (Operation chief) and Daisuke Tanimoto (Visiting researcher).

Shigeru Matsuzaka is an IVS Directing Board member (Networks Representative). Yoshihiro Fukusaki is in charge of SYOWA experiment analysis, although he is not a regular staff member.

4. Current Status and Activities

Table 4 lists all of the regular experiments that TSUKUB32 performed in 2004. The total number of experiments increased from 74 in 2003 to 108 this year. Details of this increase are as follows: 28 more UT1 experiments with the K4 or the K5 system, 5 more experiments with the Mark IV system and 1 more JADE experiment. As for the regular experiments listed in Table 4, we have added 34 experiments compared with last year. Most of them were UT1 experiments with K4 or K5 system. The number of other regular experiments with the Mark IV (VLBA) system has increased by 5 experiments compared with the past few years. In UT1, we had 60 intensive sessions with the TSUKUB32—WETTZELL baseline, performing not only on Saturday but also on Sunday starting in August 2004. The results of these sessions are shown in Figure 2. The UT1 Intensive sessions on the last Sunday of every month were performed with the K5 recording system (Figure 3). The Mark 5 data recorded at WETTZELL were transferred to the Tsukuba VLBI Correlator via internet and were converted to K5 data. In some of these sessions, we completed the data processing within 2 days after observations. We also carried out an extra UT1 session on 19th February. This session was for the Jet Propulsion Laboratory (JPL) to make a position prediction for the probe Opportunity for its landing on Mars.

Table 4. The regular experiments at Tsukuba 32-m VLBI station in 2004

Experiment	Code	Number
IVS-R	R1106,07,08,10,11,16,20,24,25,26,28,29,30,38,39,46,48,49,51,52,53,54	22
IVS-T	T2027,2028,2029,2034	4
IVS-R&D	RD0404,0405,0408	3
VLBA	RDV43,45,46,47,48	5
APSG	APSG14,15	2
JADE	JD0401-0412	12
UT1	K04010-K04354	60
Total		108

In international experiments, the K5 system was used also in the IVS-R&D sessions. In these sessions, the K5 data recorded at TSUKUB32 were transferred to MIT Haystack Observatory via a large-capacity network and were recorded on Mark 5 diskpacks after data conversion.

In domestic experiments, 3 of total 12 JADE sessions were carried out with parallel recording both on the K4 and the K5 system: JADE-0405, JADE-0408, and JADE-0410. In 2004 as in previous years, the JADE experiments, while being open to any VLBI stations with the K4 and/or the K5 recording system, had several participating stations from outside, including GIFU11 and VERAMZSW. All of the results are available on our website:

(http://vldb.gsi.go.jp/sokuchi/vlbi/sess/index.html)

We utilized "Super-SINET", a very high-speed optical fiber network (2.4 Gbps) installed at TSUKUB32 in 2002, to perform a number of real-time VLBI observations. These included some of the JADE sessions for system accuracy verification that were recorded both on the K4 and K5 recording system at both TSUKUB32 and GIFU11, as well as a number of mass data transfers, including UT1 and IVS-R&D mentioned above.

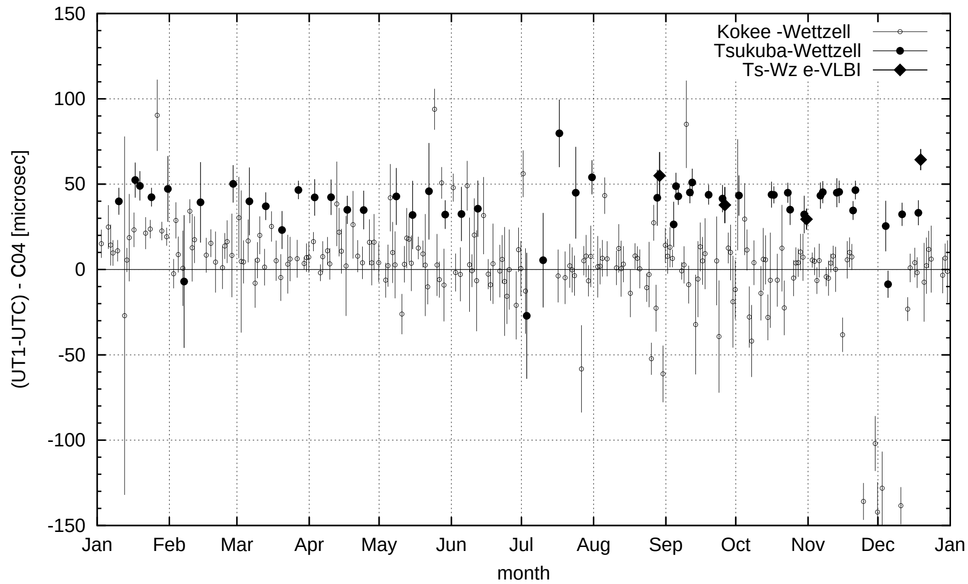

Figure 2. The results of UT1 sessions

Figure 3. K-5 sampling/recording system

5. Future Plans

In 2004, using the K5 recording system in some of our sessions, we developed the K5 control utilities with the Field System. In 2005, all of the domestic experiments and the UT1 sessions will be performed with the K5 system. As for the IVS series, we hope to use the K5 recording system with network data transfer in all of our assigned sessions. We are aiming to increase the number of our regular international sessions by reducing the cost of labor and data transfers in running the K4 system.

References

[1] Wada, K., S. Kurihara, K. Takashima: Tsukuba 32m VLBI station, in IVS 2003 Annual Report, edited by N. R. Vandenberg and K. D. Baver, NASA/TP-2004-212254, 2004.

Nanshan VLBI Station Report

Liu Xiang, Chen Maozheng

Abstract

We briefly report the activities and status of Nanshan VLBI station in 2004. The VLBI back-end has been upgraded to Mark 5A, and the Team China 3 visited the station in May.

1. Nanshan VLBI Station

The station is located about 70 km south of Urumqi, the capital city of Xinjiang Uigur Autonomous Region of China. The station is affiliated to Urumqi Astronomical Observatory of National Astronomical Observatories, Chinese Academy of Sciences. We are contributing to IVS in geodetic VLBI observations, as a network station.

2. Parameters of the System

We give some basic information of the VLBI system in Table 1.

Table 1. Some parameters of the VLBI system

parameters	**freq. range**
1.3cm, LCP, Tsys=190K, DPFU=0.057	22100-24000
3.6cm, RCP, Tsys=50K, DPFU=0.093	8200-8600
6cm, dual, Tsys=22K, DPFU=0.105	4720-5110
13cm, RCP, Tsys=75K, DPFU=0.096	2150-2320
18cm, dual, Tsys=21K, DPFU=0.088	1400-1720
30cm, LCP, Tsys=160K, DPFU=0.06	800-1200
92cm, LCP/RCP, Tsys=200K, DPFU=0.066	314-340
mk5A, mk4, mk2	available
antenna AZ/EL, size 25m	
GPS & TAC	

3. Staff

The staff is listed in Table 2. Most of the people are actively contributing to the IVS. The new director Dr. Wang Na and the new general engineer Ali Yusup will be nominated in the future.

4. Activities

In 2004, we have been involved in 12 IVS sessions, but we lost two sessions for LO problem, one for power failed and probably one for H-maser problem. We regularly participated in the

Table 2. Staff and their positions

staff	position
Dr Wang Na	station chief, n.wang@ms.xjb.ac.cn
Dr Liu Xiang	vlbi scientist, vlbi friend, liux@ms.xjb.ac.cn
Ali Yusup	antenna and general engineer, aliyu@ms.xjb.ac.cn
Chen Maozheng	receiver and back-end engineer, mzhchen@ms.xjb.ac.cn
Sun Zhengwen	receiver engineer
Wang Weixia	receiver engineer
Yang Wenjun	back-end and vlbi operator
Zhang Hua	vlbi operator
Li Guanghui	network manager
Ma Jun	receiver maintain
Wang Shiqiang	antenna maintain
Chen Chengyu	antenna maintain

EVN observations, Urumqi-Shanghai baseline satellite observations, Sino-Japan VLBI test and especially the Huygens international VLBI observations (with LCP in S-band at the last time!).

We successfully completed the Mark 5A upgrade at the station in Feb. 2004, become a Mark 5A station for geodesy. We invited Chopo Ma, Ed Himwich, Brian Corey, Richard Strand (called Team China 3) to visit the station in May in order to settle some problems and give training. It was a fruitful visit: we together fixed problems, e.g. 3 wrapped VCs etc., upgraded the Mark 5 and FS softwares, did sampler statistics and VC linearity measurements.

In addition, we upgraded 6cm band to dual polarization with a receiver system made by Max-Planck-Institute für Radioastronomie in Bonn in August. We installed a new 30cm feed on the primary focus, being available for observation.

5. Future Plan

We plan to have a new H-maser and upgrade the antenna control system and the S/X receiver system for Chinese Lunar project in 2005-2006. A new feed for both 92cm and 49cm band is also planned.

Westford Antenna

Mike Poirier

Abstract

Technical information is provided about the antenna and VLBI equipment at the Westford site of Haystack Observatory, and about changes to the systems since the 2003 IVS Annual Report.

1. Westford Antenna at Haystack Observatory

Since 1981 the Westford antenna has been one of the primary geodetic VLBI sites in the world. Located ~70 km northwest of Boston, Massachusetts, the antenna is part of the MIT Haystack Observatory complex.

Figure 1. The radome of the Westford antenna.

The Westford antenna was constructed in 1961 as part of the Lincoln Laboratory Project West Ford that demonstrated the feasibility of long-distance communication by bouncing radio signals off a spacecraft-deployed belt of copper dipoles at an altitude of 3600 km. In 1981 the antenna was converted to geodetic use as one of the first two VLBI stations in the National Geodetic Survey Project POLARIS. Westford has continued to perform geodetic VLBI observations on a regular basis since 1981. Westford has also served as a test bed in the development of new equipment and techniques now employed in geodetic VLBI worldwide. Primary funding for geodetic VLBI at Westford is provided by the NASA Space Geodesy Program.

Table 1. Location and addresses of Westford antenna.

Longitude	71.49° W
Latitude	42.61° N
Height above m.s.l.	116 m
MIT Haystack Observatory Off Route 40 Westford, MA 01886-1299 U.S.A.	
http://www.haystack.mit.edu	

2. Technical Parameters of the Westford Antenna and Equipment

The technical parameters of the Westford antenna, which is shown in Figure 2, are summarized in Table 2.

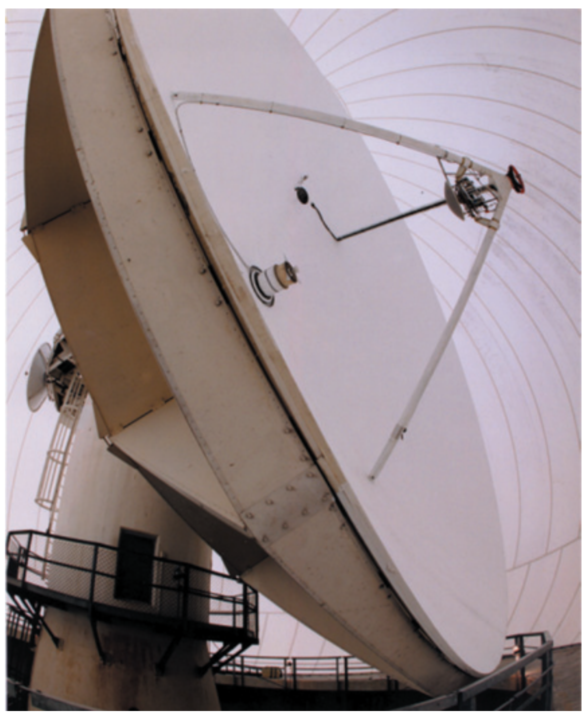

Figure 2. Wide-angle view of Westford antenna inside the radome. The VLBI S/X receiver is located at the prime focus. The subreflector in front of the receiver is installed when observing with the TAL receiver (see Section 4), which is located at the Cassegrain focus.

The antenna is enclosed in a 28-meter-diameter, air-inflated radome made of 1.2-mm-thick, Teflon-coated fiberglass – see Figure 1. When the radome is wet, system temperatures increase by 10–20 K at X-band and by a smaller amount at S-band. The major components of the VLBI data acquisition system are a Mark IV electronics rack, a Mark IV tape drive, which is used for recording thin tapes only, a Mark 5A recording system, and a Pentium-class PC running PC Field System

Table 2. Technical parameters of the Westford antenna for geodetic VLBI.

Parameter	*Westford*	
primary reflector shape	symmetric paraboloid	
primary reflector diameter	18.3 meters	
primary reflector material	aluminum honeycomb	
S/X feed location	primary focus	
focal length	5.5 meters	
antenna mount	elevation over azimuth	
antenna drives	electric (DC) motors	
azimuth range	$90° - 470°$	
elevation range	$4° - 87°$	
azimuth slew speed	$3° \ s^{-1}$	
elevation slew speed	$2° \ s^{-1}$	
	X-band system	*S-band system*
frequency range	8180-8980 GHz	2210-2450 GHz
T_{sys} at zenith	50–55 K	70–75 K
aperture efficiency	0.40	0.55
SEFD at zenith	1400 Jy	1400 Jy

version 9.6.9. The primary frequency and time standard is the NR-4 hydrogen maser. A CNS Clock GPS receiver system provides independent timing information and comparisons between GPS and the maser. Westford also hosts the WES2 GPS site of the IGS network. A Dorne-Margolin chokering antenna is located on top of a tower ~60 meters from the VLBI antenna, and a Turbo Rogue receiver acquires the GPS data. A meteorology package provided by the NOAA Forecast Systems Laboratory continually logs meteorological data, which are downloaded daily and are available from the IGS and cignet archives.

3. Westford Staff

The personnel associated with the VLBI program at Westford and their primary responsibilities are:

John Ball	pointing system software
Joe Carter	antenna controls
Dave Fields	technician, observer
Brian Corey	VLBI technical support
Glenn Millson	observer
Michael Poirier	site manager
Alan Whitney	site director

4. Status of the Westford Antenna

During the period 2004 January 1 - 2004 December 31, Westford participated in a total of 72 24-hour geodetic experiments. Westford participated regularly in the IVS-R1, IVS-R&D, and RD-VLBA series of geodetic experiments, as well as five IVS-T2 sessions and various fringe tests and e-VLBI experiments.

The Mark5A is our primary recording system on site. All the geodetic sessions use the Mark5A with the exception of the RD-VLBA experiments which are recorded using the Mark IV tape drive.

There were a few failures at Westford during this operational period. In January 2004 we lost a stage in the S-band LNA which was replaced. In April 2004 our LO system failed in the receiver and we replaced it with a CTILO. In June 2004 and November 2004 our S-Band LNA failed but was repaired by replacing the dewar.

Use of the Westford antenna is shared with the Terrestrial Air Link (TAL) Program operated by the MIT Lincoln Laboratory. In this project Westford serves as the receiving end on a 42-km-long terrestrial air link designed to study atmospheric effects on the propagation of wideband communications signals at 20 GHz.

5. e-VLBI Development at Westford

Westford continues to play a key role in the development of e-VLBI. In 2004, a number of e-VLBI demonstration experiments were carried out; among the notable achievements:

- Rapid-turnaround experiments between Westford and Kashima have yielded UT1 results in as little as 4+ hours!
- Real-time e-VLBI experiments (i.e. no disk buffering) were conducted with GGAO at data rates of 512 Mbps, including real-time display of real-time correlation results at the Super Computer 2004 conference in Pittsburgh in November 2004.
- Real-time e-VLBI experiments with Onsala were conducted at rates up to 128 Mbps.
- A 10Gbps data link was established between the Westford site and the Haystack site; we plan to use this link in 2005 to do testing of e-VLBI data rates as high as 4 Gbps.

6. Outlook

We anticipate Westford will be able to participate in the 72 24-hour geodetic experiments, the CONT05 tentatively planned for early fall, and the many e-VLBI experiments during 2005.

Fundamentalstation Wettzell - 20m Radiotelescope

Richard Kilger, Gerhard Kronschnabl, Wolfgang Schlüter, Rudolf Zernecke

Abstract

In 2004 the 20m-Radiotelescope Wettzell contributed strongly to the IVS observing program. The transition to the Mark 5A system has been completed and the system is used for routine operation. A 34Mbps Internet link has been installed. In particular the Intensive observations were the candidates for e-VLBI activities. Technical changes, improvements and upgrades have been done to increase the reliability of the entire system.

1. General Information

The Radiotelescope Wettzell (RTW) is jointly operated by the Bundesamt für Kartographie und Geodäsie (BKG) and the Forschungseinrichtung Satellitengeodäsie/Technical University of Munich (FESG) within the frame of the Forschungsgruppe Satellitengeodäsie (FGS).

At the Fundamentalstation Wettzell (FSW) the 20m Radiotelescope (RTW) for VLBI is collocated with 3 other geodetic space technique systems:

- the laser ranging system WLRS (Wettzell Laser Ranging System) designed for SLR and LLR,
- several GPS receivers, integrated in the global IGS, the European GPS, and in the national GPS network, and for time transfer experiments,
- a DORIS station on loan from CNES/France.

At the Wettzell observatory, the first ringlaser “G” dedicated to the monitoring of the variations in Earth rotation has been developed in close cooperation with the University of Canterbury, New Zealand. The system was established in 1998 to 2001 and is operating since fall 2001. “G” is sensitive to monitoring daily variations better than 10^{-8} relative accuracy.

Additional in situ observations were carried out such as

- gravity observations, employing a super conducting gravity meter
- earthquake observations with a seismometer
- meteorological observations to monitor pressure, temperature and humidity, rain fall, wind speed, wind direction and also
- water vapour observations with a radiometer.

A Time and Frequency system (T&F) is established for the generation of timescales (UTC(IfAG)) and for the provision of very precise frequencies needed for VLBI, SLR/LLR and GPS observations, employing Cs-clocks and H-Masers and GPS time receivers. The time scale UTC(IfAG) is published in the monthly Bulletin T of the BIPM.

2. Staff

The staff of the Fundamentalstation Wettzell consists in total of 35 members for operating, maintaining and improving all the devices, and developing new systems. Within the responsibility of the Fundamentalstation Wettzell, are the TIGO systems, operated in Concepción-Chile jointly with a Chilean partner consortium with 3 experts from Wettzell, and the O'Higgins station, jointly operated with the German Space Center (DLR) and the Institute for Antarctic Research Chile (INACH). The staff operating the 20m Radiotelescope Wettzell (RTW) is summarized in the Table 1.

Table 1. Staff - members

Name	**Affiliation**	**Function**	**Working for**
Wolfgang Schlüter	BKG	head of the FSW	RTW, TIGO, O'Higgins
Richard Kilger	FESG	group leader RTW	RTW
Erhard Bauernfeind	FESG	mechanical engineer	RTW
Ewald Bielmaier	FESG	technician operator	RTW
Christian Hupf	FESG/BKG	student	RTW
Gerhard Kronschnabl	BKG	electronic engineer	RTW, TIGO (partly), O'Higgins (partly)
Christian Plötz	BKG/FESG	electronic engineer	O'Higgins, RTW
Raimund Schatz	FESG	software engineer	RTW (partly)
Walter Schwarz	BKG	electronic engineer	RTW, O'Higgins
Reinhard Zeitlhöfler	FESG	electronic engineer	RTW
Rudolf Zernecke	FESG	survey engineer	RTW, TIGO (partly)

3. Observations in 2004

RTW has participated in various IVS observing programs: R1, R4, T2, R&D, as well as VLBA and Europe. All these sessions run for 24 hours.

Additionally RTW participates in single baseline sessions to determine changes in rotational speed (UT1-UTC). These sessions are done once a day with 1 hour data recording and are called Intensives. This type of session is predestined to transfer recorded data by e-VLBI: the amount of recorded data is relatively small (35 Gbytes) and the interest to get results immediately after the observations is very high. Currently there are two types of Intensives:

- INT1 observed between Kokee and RTW from Monday through Friday.
- INT2 observed between Tsukuba and RTW on Saturday and Sunday.

The number of sessions done in 2004 is listed in Table 2.

INT1 is performed since April 1984 continuously with radiotelescopes in the US (Westford, Greenbank and Kokee). Presently INT1 is recorded with the Mark 5 system onto a single fixed disk. Starting August 06, RTW supported transfer of data via e-VLBI for 2 months. (Due to problems outside of Wettzell data transfer via e-vlbi has been stopped.)

Table 2. RTW's participation in IVS 24 hr and 1 hr observing programs

program	number of 24h-sessions
IVS R1	50
IVS R4	50
IVS T2	9
IVS R&D	10
VLBA	5
EUROPE	4
in total	**128**

program	number of 1h-sessions
INT1	211
INT2	60
in total	**271**

INT2 is a second single baseline Intensive session that is observed between Tsukuba and RTW and started in 2003. Data are recorded with K4-DAT on cassettes and correlated in Japan. From January until August 2004 the observation was performed on Saturdays. Starting in September 2004 observations were done also on Sundays. From that time 7 Sunday INT2 took place at Wettzell. The last Sunday of the month, the data are transferred via e-VLBI to Japan (without sending a tape or a disk in parallel). It is highly desirable to transfer the data via internet from a scientific point of view and cost of transportation.

4. Maintenance

The intensive use of RTW requires maintenance in particular to avoid failures during the observations. Some problems were caused by failures of the receiver cooling system during the hot summer period. The antenna control unit (ACU) fails randomly for reasons unknown. At the end of 2004 the ACU was replaced by a new one.

5. Technical Improvements

The transition from Mark IV to Mark 5A was successfully completed. Two Mark 5A systems were integrated (Figure 1). One of the units was modified for the Intensive observations as Intensives only require one disk per experiment and not a complete 8 pack. The second unit is used as spare and also to test and to develop e-VLBI procedures. The tape drives are still available.

For e-VLBI a 34Mbps internet connection is installed. Due to the policy of German Telecom, the higher rate of 155Mbps or even more is still much too expensive. The link in Wettzell can be extended to 155Mbps, as soon as it becomes affordable. The 34Mbps link allows the transmission of the Intensive data to the correlator. It is used monthly to send the Sunday INT2 observations to Kashima/Tsukuba. First tests with Haystack and USNO, which has access to high speed internet via ISI, located in the neighbourhood of USNO in Washington, were conducted in order to ship the INT1 observations.

To improve the reliability the following actions were taken:

1. Two new PCs (one as back-up) with the latest version of the Field System replaced the old

Figure 1. 2 MK5A systems, one with modifications for the Intensives (left); New Antenna Control Unit (ACU) (right)

PCs.

2. The un-interruptable power supplies (UPS), which support all the components of the Data Acquisition System, including Mark IV, Mark 5 and K4 was completely renewed, as the previous system did not meet the growing requirements. A total survival period of more than one hour is realized now.

3. The Dewar system has been improved through new vacuum valves and an automatic pumping station for better and faster maintenance.

4. The old Antenna Control Unit (ACU), which employed a PC with an old MS DOS operating system and which caused several unexpected failures of the antenna, was replaced together with related hardware and interfaces. The new ACU is based on the real time operating system "VxWorks". First experiences with the new ACU are promising, though some minor points still need improvements.

6. Upgrade Plans for 2005

During 2005 it is planned to make more use of the e-VLBI facilities and to increase the connection from 34Mbps to at least 155Mbps. Further, an upgrade of the Mark 5A to Mark 5B is foreseen.

Observatorio Astronómico Nacional – Yebes

Francisco Colomer

Abstract

This report updates the description and details of the OAN facilities as an IVS network station. The construction of the new 40-meter radiotelescope has progressed substantially, after the main parabolic reflector and subreflector have been lifted on top of the concrete tower. Completed construction in 2005 will allow the installation of a new S/X band receiver, in order to restart the geodetic VLBI observations in 2006. The institute staff is also involved in technical developments, and scientific research in geodesy, astrometry and astrophysics.

Figure 1. Erection of the new 40 meter radiotelescope of OAN at Yebes (Guadalajara, Spain).

1. General Information: The OAN Facilities

The Observatorio Astronómico Nacional (OAN) of Spain, which is a department of the Instituto Geográfico Nacional (IGN, Ministerio de Fomento), operates a 14 meter radiotelescope at Yebes (Guadalajara, Spain). This facility is a network station of the IVS, and has participated regularly in the geodetic VLBI campaigns to study the tectonic plate motions in Europe, Earth rotation, and pole motion.

The VLBI equipment has been constantly upgraded (including a Mark 5A unit), and is fully operational. The institute is currently involved in the construction of a new 40 meter radiotelescope (see Fig. 1) which is expected to be available for geodetic VLBI observations in 2006. Progress can be followed at the web address (in Spanish):

`http://www.oan.es/ign/home/astronomia/instalaciones/telescopios/40m/40m.html`

2. OAN Staff Working in VLBI Projects

Table 1 lists the OAN staff which are involved in VLBI studies, some of which can be found at the telescope (CAY) address. The associated members of IVS are indicated with an asterisk. Contact information is provided at the URL:

`http://www.oan.es/investigacion/astronomia/vlbi.shtml`

The VLBI activities are also supported by other staff like receiver engineers, computer managers, secretaries and students.

Table 1. Staff in the OAN VLBI group (Email: **vlbitech@oan.es**).

Name	Background	Role	Dedication	Address
Rafael Bachiller	Astronomer	Director of OAN	10%	OAN
Alberto Barcia	Engineer	Chief engineer	10%	CAY
Francisco Colomer*	Astronomer	VLBI Project coordinator	30%	OAN
Jean-Francois Desmurs	Astronomer	Scientist (Astrophysics)	10%	OAN
Jesús Gómez–González*	Astronomer	General Subdirector for Geodesy and Geophysics	10%	IGN
José Antonio López–Fdez	Engineer	CAY site manager	20%	CAY
Maria Rioja*	Astronomer	Scientist (Astrometry)	50%	OAN
Pablo de Vicente*	Astronomer	VLBI Technical coordinator	30%	CAY

3. Status of the Geodetic VLBI Activities at OAN

The main contribution of OAN to IVS is the realization of geodetic VLBI observations: the OAN 14-m radio telescope at Yebes has however not participated in any VLBI campaigns in 2004 due to the failure of the very old telescope control computer (HP1000).

Therefore most of the activities focused on the construction of the new 40-m radiotelescope. The configuration of the VLBI receivers was fully designed and the construction of the different elements started. The system consists of several mirrors, called auxiliary, that direct the beam from the nasmyth mirrors to the receivers. Up to seven frequency bands can be supported: S, X, C, Ku, 22 GHz and 30 GHz. This configuration allows simultaneous observations with at least two receivers.

Up to the moment, three receivers have been designed. All of them are based on cryogenically cooled HEMT amplifiers with simultaneous double circular polarisation. The construction of the optical configuration of the VLBI receivers will be finished by the end of March 2005 (Fig. 2). For simultaneous observation with the S and X receivers, a parabolic and a dichroic mirrors have been constructed and tested. An elliptical reflector has been constructed for the 22 GHz optics.

The movement of these mirrors is remotely controlled and the selection between receivers will be done in terms of seconds. The horns and polarizers for the three receivers have been constructed and tested in an anechoic chamber. The 22 GHz receiver, including the cryostat (Fig. 3), is fully constructed and presents very low noise (less than 18 K from 21 to 24 GHz). The S and X receivers are fully designed and most parts of their components are already in our laboratories.

The first observations with these three receivers are scheduled after summer 2005. The instrument will start operations for the IVS at S/X bands in 2006.

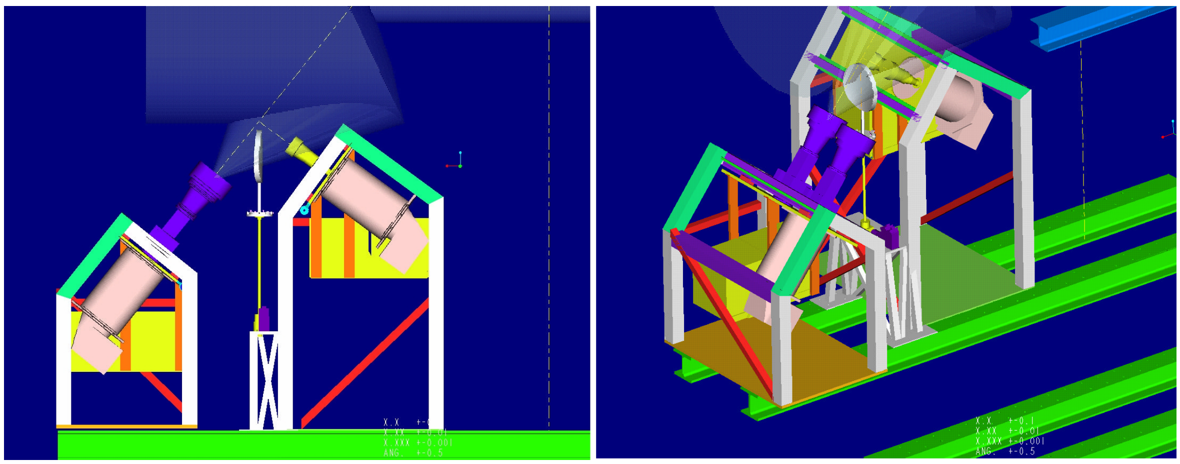

Figure 2. Optical configuration of the 40 meter radiotelescope S/X bands.

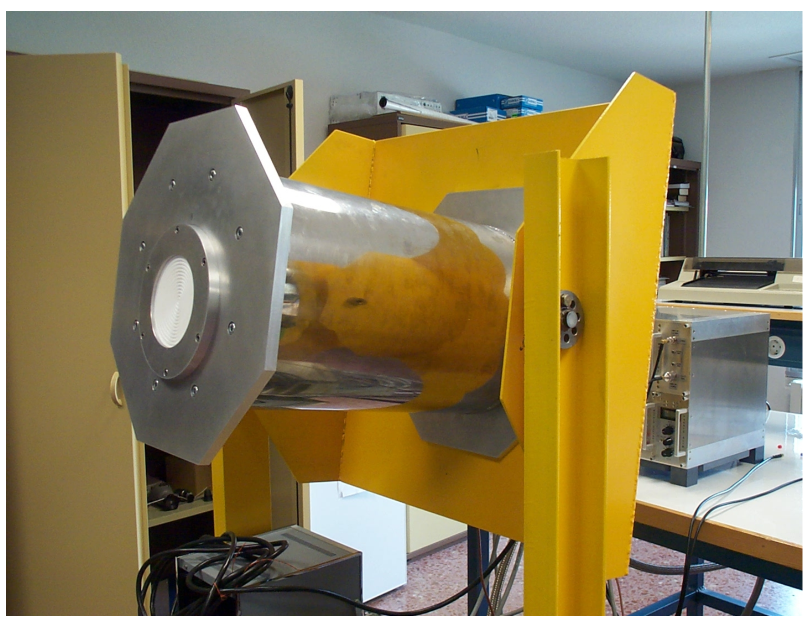

Figure 3. Cryostat of the 40-m telescope 22 GHz VLBI receiver.

The OAN group performs high precision astrophysical VLBI studies of maser emission towards late-type stars, which will not be discussed here. However we point out the case of high precision astrometric studies applied to the joint determination of proper motion of H_2O masers and distances to emitting stars, with the analysis of multiple VLBI campaigns in the course of 1 year, at 22 GHz (Rioja et al. 2004). The development of new observational and analysis strategies will allow the extension of this work to higher frequencies, to study "bona fide" proper motions of SiO masers at 43 and 86 GHz.

Also, the new Japanese interferometer, VERA, with its innovative dual-beam system will make possible the extension of these absolute astrometric studies to higher frequencies (Honma et al. 2004).

4. Future Plans

The construction of the new 40 meter radiotelescope at Yebes is progressing well. The erection of the main reflector was carried out in December 2004. This telescope is expected to be operational at S/X bands in mid 2006. Other frequencies of operation will be 4-7 GHz, 10-15 GHz, 21-24 GHz (first light receiver), 30-32 GHz, 40-50 GHz, and 72-116 GHz.

On the other hand, measurements of absolute gravimetry at the 14-m telescope building have been performed. A project of construction of a building is being finalized, which will allow the installation of permanent equipment for constant gravity monitoring. The Yebes site will become a fundamental geodetic station after collocation of three geodetic techniques (VLBI, GPS and gravimetry) is achieved in 2005. More information at the web site (in Spanish):

`http://www.ign.es/ign/home/geodesia/gravimetria.htm`

Finally, we expect to connect the Yebes site to GEANT (the high speed transeuropean data network) by the end of 2005.

References

[1] M. Honma et al (incl M. Rioja): "VERA Observation of the W49N H_2O Maser Outburst in 2003 October". Publications of the Astronomical Society of Japan, Vol.56, No.3, pp. L15-L18, 2004.

[2] M.J. Rioja, R. Cesaroni, L. Moscadelli: "Astrophysical applications of precision astrometry". Proceedings of the 7th EVN Symposium, held in Toledo (Spain), 2004. (see `http://www.oan.es/evn2004/`).

Yellowknife Observatory

Mario Bérubé, Anthony Searle

Abstract

The Yellowknife VLBI antenna is a 9 meter diameter antenna which was formerly the "MV-1" mobile antenna. The MV-1 was a proof-of-concept for mobile VLBI and in 1991 NASA and NOAA offered the system for use at Yellowknife.

The antenna is located at the Yellowknife Geophysical Observatory and is operated by the Geodetic Survey Division, Natural Resources Canada. This report gives an update on recent activities.

Figure 1. A snowy Yellowknife Geophysical Observatory 9m antenna.

1. Overview

Formerly the "MV-1" mobile antenna, the Yellowknife antenna was used as a proof of concept for mobile VLBI under the ARIES (Astronomical Radio Interferometric Earth Surveying) program.

Following the successful proof of concept, the MV-2 and MV-3 mobile antennas were built and used extensively during NASA's Crustal Dynamics project. The MV-1 antenna was then stationed at Vandenberg Air Force Base. In 1991 NASA and NOAA offered the system to Energy, Mines and Resources, Canada, for use at Yellowknife. With support of the Crustal Dynamics Project the Yellowknife VLBI observatory came on the air in the summer of 1991.

The antenna is located at the Yellowknife Geophysical Observatory and is operated by the Geodetic Survey Division, Natural Resources Canada. The Yellowknife Geophysical Observatory is operated by the Geological Survey of Canada, Pacific Division, Natural Resources Canada.

2. General Specifications

- Latitude : 62.48 North
- Longitude : 114.48 West
- Reflector : 9m
- Receiver : S and X cryogenic
- Azimuth speed : 40 degrees per minute
- Elevation speed : 40 degrees per minute
- PCFS version : 9.5.3
- VLBI equipment : Mk III and thick tape drive. S2 data acquisition and recording terminal.
- Time standard : NR Maser
- GPS receiver : BenchMark

3. Antenna Improvements

Since being installed in Yellowknife, the MV-1 has not required any major upgrades. The antenna is parked every winter because the antenna is unable to operate in low temperatures (November till March). Once spring arrives, the Yellowknife team prepares the antenna for the upcoming season.

Mechanical maintenance was performed in 1998 and the antenna has performed reasonably reliably since.

4. Antenna Survey

The Yellowknife antenna is surrounded by a high precision survey network which has been measured three times since 1990. This network has been precisely measured to obtain the geodetic tie between the VLBI, the GPS and the DORIS reference points with a precision of a few mm.

5. Operations January 2004 - December 2004

In 2004, Yellowknife was involved in 4 IVS–T2 (Terrestrial Reference Frame sessions), and in 6 IVS–E3 sessions.

Operation Centers

The Bonn Geodetic VLBI Operation Center

A. Nothnagel, D. Fischer, A. Müskens

Abstract

In 2004 the GIUB Operation Center has continued to carry out similar tasks of organizing and scheduling various observing series as in 2003.

1. Center Activities

The GIUB VLBI Operation Center is located at the Geodetic Institute of the University of Bonn, Nussallee 17, D-53115 Bonn, Germany. It has been organizing and scheduling VLBI observing sessions for more than twenty years. The observing series organized and scheduled in 2004 are the same as in 2003:

- **Tsukuba - Wettzell UT1-UTC K4 Intensive Series**
  The Tsukuba - Wettzell Intensive series for monitoring UT1-UTC has been continued and expanded as a joint project of the Bundesamt für Kartographie und Geodäsie (BKG, Germany), the Geographical Survey Institute (GSI, Japan) and the Geodetic Institute of the University of Bonn (GIUB, Germany).

  Regular one hour sessions have been observed almost every Saturday in 2004. Starting on August 29th, 2004 a second INT2 session per week has been established on Sundays. One Sunday session per month is observed as eVLBI session to test and evaluate the procedure. Based on the experience from almost two years of Wettzell - Tsukuba Intensives the schedule design and strategy have been refined in close collaboration with the Goddard Space Flight Center and the GSI correlator.

  In order to assess the accuracy of UT1-UTC determined with both Intensive series (INT1 and INT2), two special 24-hour Research and Development experiments (RD0404 and RD0405) have been carried out. In the first session Wettzell and Kokee Park observed 24 consecutive single-baseline sessions while 6 other globally distibuted stations observed a normal 24-hour session. In the second session the same procedure was repeated for the Wettzell - Tsukuba baseline. Since the UT1 results of a global multi-baseline session are expected to be better by a factor of 4-6 than those of single-baseline Intensive observations, the comparison will provide information about the accuracy level of the Intensive UT1 results and on consistency questions. A third 24-hour R&D session (RD0408) was scheduled for testing strategy improvements of the Intensive sessions. Here the 24 consecutive Intensive sessions have been observed using the 1 Gb/sec technology and a different scheduling procedure.

- **IVS-T2 series**
  This series is being observed roughly once per month (11 sessions in 2004) primarily for maintenance and stabilisation of the VLBI terrestrial reference frame as well as for Earth rotation monitoring as a by-product. Each station of the global geodetic VLBI network participates several times per year in the T2 sessions. The IVS Observing Program Commitee (OPC) decided to enlarge the T2 sessions from 8 or 9 stations to 16 to 20 for a stronger and more robust determination of the TRF. The scheduling of these sessions has to take into

account that a sufficient number of observations is planned for each baseline of these global networks. The experience from the processing of these experiments has confirmed that the Mark IV correlators can efficiently handle large sessions requiring multiple passes when data is recorded predominantly with Mark 5 units.

- **Measurement of Vertical Crustal Motion in Europe by VLBI (EUROPE)**
  Four sessions with Ny-Ålesund, Onsala, Wettzell, Simeiz, Madrid (DSS65), Yebes, Medicina, Matera, Noto, Svetloe, and Effelsberg (participated once) have been scheduled for precise station coordinate determination and long term stability tests. MPIfR operated a Water Vapor Radiometer at Effelsberg during the last Europe session.
- **Southern Hemisphere and Antarctica Series (OHIG):**
  Four sessions with the Antarctic stations Syowa (Japanese) and O'Higgins (German) plus Fortaleza, Hobart, Kokee, HartRAO and DSS45 have been organized for maintenance of the VLBI TRF and Earth rotation monitoring. O'Higgins is also included in the T2 sessions.

2. Staff

Table 1. Personnel at GIUB Operation Center

Dorothee Fischer	++49-228-732623	dorothee.fischer@uni-bonn.de
Arno Müskens	++49-228-525264	mueskens@mpifr-bonn.mpg.de
Axel Nothnagel	++49-228-733574	nothnagel@uni-bonn.de

On July 1, 2004, Axel Nothnagel handed over the responsiblity for scheduling the Europe sessions to Arno Müskens. Arno is also responsible for the T2 and the OHIG sessions. Dorothee Fischer organized the Tsukuba - Wettzell series.

CORE Operation Center Report

Cynthia C. Thomas, Daniel MacMillan

Abstract

This report gives a synopsis of the activities of the CORE Operation Center from January 2004 to December 2004. The report forecasts activities planned for the year 2005.

1. Changes to the CORE Operation Center's Program

The Earth orientation parameter goal of the IVS program is to attain precision at least as good as 3.5 μs for UT1 and 100 μas in pole position.

The IVS program was started in 2002 and used the Mark IV recording mode for each session. The IVS program began using the Mark 5 recording mode in mid 2003. Most stations were using the Mark 5 recording mode by the end of 2004. This change resulted in the 2004 sessions being processed more efficiently and freeing up correlator time. As a result, the program became station and media dependent rather than correlator dependent. The following are the network configurations for the sessions for which the CORE Operation Center was responsible:

IVS-R1: 52 sessions, scheduled weekly on Mondays, seven station network
RDV: 6 sessions, scheduled evenly throughout the year, 18 to 20 station network
IVS-R&D: 10 sessions, scheduled monthly, two to eight station networks

2. IVS Sessions January 2004 to December 2004

This section displays the purpose of the IVS sessions for which the CORE Operations Center is responsible.

- IVS-R1: In 2004, the IVS-R1s were scheduled weekly with a seven station network. There was a core network for each day plus three other stations. Matera was scheduled as a core station but Matera went down at the beginning of the year due to rail problems. By the end of 2004, Fairbanks and Tsukuba were the only participating stations recording on Mark IV tapes.

  The purpose of the IVS-R1 sessions is to provide weekly EOP results on a timely basis. These sessions provide continuity with the previous CORE series. The "R" stands for rapid turnaround because the stations, correlators, and analysts have a commitment to make the the time delay from the end of recording to results as short as possible. The time delay goal is a maximum of 15 days. Participating stations are requested to ship tapes to the correlator as rapidly as possible. The "1" indicates that the sessions are on Mondays.

- RDV: There are six bi-monthly coordinated astrometric/geodetic experiments each year that use the full 10-station VLBA plus up to 10 geodetic stations.

  These sessions are being coordinated by the geodetic VLBI programs of three agencies: 1. USNO will perform repeated imaging and correction for source structure; 2. NASA will analyze this data to determine a high accuracy terrestrial reference frame; and 3. NRAO will use these sessions to provide a service to users who require high quality positions for a small number of sources. NASA (the CORE Operation Center) prepares the schedules for the RDV sessions.

- R&D: The purpose of the 10 R&D sessions in 2004, as decided by the IVS Program Committee, was to record at 1 Gbit/s data rate to evaluate the geodetic results. Those experiments also tested the entire data flow from scheduling through analysis for the higher data rate. Participating stations varied depending on when stations were equipped with Mark 5 systems.

  A second type of R&D session was proposed and observed, with the purpose of comparing UT1 from 1-hour Intensive sessions with UT1 from simultaneous 24-hour sessions. In these R&D sessions sequential 1-baseline hour-long Intensive sessions were recorded in parallel with a 6-station network.

3. Current Analysis of the CORE Operation Center's IVS Sessions

Table 1 shows the average formal errors for R1, R4, RDV, and T2 sessions from 2004. The R1, R4, and RDV uncertainties are within 10-15% of the corresponding values from 2003. T2 uncertainties are better by 30-40%.

In Table 2, we show the differences between EOP from the different session types and the IGS combined EOP series. The small number of RDV sessions makes it difficult to draw any statistically significant conclusions. The offset differences are at about the same level in 2003 and 2004 for all sessions. The Y-pole offsets for all sessions are remarkably close together, however the X-pole offset for the R4 sessions should be investigated. WRMS differences are larger in 2004 (only about 10% for the R1s). We should note that comparisons with the IERS C04 series are now problematic because errors have been introduced into the series from other VLBI analysis centers not properly modeling the displacement at Gilcreek due to the Denali Earthquake. For instance, the WRMS differences of our EOP (X,Y, UT1) series relative to C04 are 40% to 100% larger in 2004 than in 2003.

Table 1. Average EOP Formal Uncertainties for 2004

Session Type	X-pole (μas)	Y-pole (μas)	UT1 (μs)	DPSI (μas)	DEPS (μas)
R1	61	62	2.4	138	56
R4	90	78	3.2	177	71
T2	98	85	3.9	215	79
RDV	37	40	1.9	76	30

4. The CORE Operations Staff

Table 3 lists the key technical personnel and their responsibilities so that everyone reading this report will know whom to contact about their particular question.

Table 2. Offset and WRMS Differences (2004) Relative to the IGS Combined Series

	Number	Offset (μas)	X-pole WRMS (μas)	Offset (μas)	Y-pole WRMS (μas)	Offset (μs/d)	LOD WRMS (μs/d)
R1	52	2(17)	94(81)	-246(-217)	101(90)	-1(-1)	16(14)
R4	51	-130(-11)	141(114)	-273(-219)	104(84)	3(2)	21(15)
T2	12	-9(40)	176(162)	-224(-222)	129(97)	-2(2)	20(12)
RDV	6	30(-21)	115(75)	-220(-154)	104(80)	-5(0)	20(9)

Values for 2003 are shown in parenthesis

Table 3. Key Technical Staff of the CORE Operations Center

Name	Responsibility	Agency
Tom Buretta	Recorder and electronics maintenance	Haystack
Brian Corey	Analysis	Haystack
Irv Diegel	Maser maintenance	Honeywell
John Gipson	SKED program support and development	NVI, Inc./GSFC
Frank Gomez	Software engineer for the Web site	Raytheon/GSFC
David Gordon	Analysis	Raytheon/GSFC
Ed Himwich	Network Coordinator	NVI, Inc./GSFC
Chuck Kodak	Receiver maintenance	Honeywell
Dan MacMillan	Analysis	NVI, Inc./GSFC
Leonid Petrov	Analysis	NVI, Inc./GSFC
Dan Smythe	Tape recorder maintenance	Haystack
Cynthia Thomas	Coordinate master observing schedule and prepare observing schedules	NVI, Inc./GSFC
Nancy Vandenberg	Organizer of CORE program	NVI, Inc./GSFC
William Wildes	Procurement of materials necessary for CORE operations	GSFC/NASA

5. Planned Activities during 2005

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2005.

- The IVS-R1 sessions will be observed weekly and recorded in a Mark IV mode. Fairbanks will start recording on Mark 5 modules. Tsukuba will record using K5 and e-vlbi. Fortaleza will join the IVS-R1 network in July 2005 after getting a Mark 5.
- The IVS-R&D sessions will be observed 10 times during the year. The purpose of the R&D sessions in 2005 as determined by the IVS Observing Program Committee is to continue studying how to use Gb/s data rate for geodesy. Phase delay will be attempted and the

SNRs will be set high.

- The RDV sessions will be observed 6 times during the year.

U.S. Naval Observatory Operation Center

Kerry Kingham, M.S. Carter

Abstract

This report covers the activities of the NEOS Operation Center at USNO for 2004. The Operation Center schedules IVS-R4 and the Intensive experiments.

1. VLBI Operations

NEOS operations in the period covered consisted, each week, of one 24-hour duration IVS-R4 observing session, on Thursday-Friday, for Earth Orientation, together with five daily one-hour duration "intensives" for UT1 determination, Monday through Friday. The operational IVS-R4 network has included VLBI stations at Gilmore Creek (Alaska), Kokee Park (Hawaii), Wettzell (Germany), Fortaleza (Brazil), Ny-Ålesund (Norway), Algonquin Park (Canada), TIGO (Chile), Svetloe (Russia), Hobart (Australia), Onsala (Sweden), and Medicina (Italy). A typical R4 consisted of 7 stations. The regular stations for the IVS-Intensives were Kokee Park and Wettzell. Svetloe participated in some IVS-Intensives when Wettzell was unavailable.

All sessions are correlated at the Washington Correlator, which is located at USNO and is run by NEOS.

2. Staff

K. A. Kingham and M. S. Carter are the only staff members of the NEOS Operation Center. Kingham is responsible for the overall managment and Carter makes the schedules. M. S. Carter has relocated to the USNO Flagstaff Station (NOFS), but continues her duties as part of the Operation Center.

Correlators

The Bonn Astro/Geo Mark IV Correlator

Alessandra Bertarini, Arno Müskens, Walter Alef

Abstract

The Bonn Mark IV VLBI correlator is operated jointly by the MPIfR and the GIUB in Bonn and the BKG in Frankfurt. In 2004 Gbit/s correlation and ftp-VLBI fringe tests were conducted successfully for the first time.

1. Introduction

The Bonn Mark IV correlator is hosted at the Max-Planck-Institut für Radioastronomie (MPIfR)[1], Bonn, Germany. It is operated jointly by the MPIfR and by the Bundesamt für Kartographie und Geodäsie (BKG)[2] in cooperation with the Geodätisches Institut der Universität Bonn (GIUB)[3]. It is a major correlator for geodetic observations and MPIfR's astronomical projects.

2. Present Status and Capabilities

Figure 1. Left: correlator surrounded by two Mark 5 playback units and two station units. Center: six rack-mounted Mark 5 playback units. Right: tape drive with station unit on top.

The Bonn correlator (Fig 1) is one of the four Mark IV VLBI data processors in the world. It has been operational since 2000. A summary of the Bonn correlator capabilities is presented in Table 1.

[1] http://www.mpifr-bonn.mpg.de/div/vlbicor/index_e.html
[2] http://www.ifag.de/index_english.htm
[3] http://www.gib.uni-bonn.de

Table 1. Correlator Capabilities

Playback Units	
Number available:	9 Mark IV tape drives, 8 Mark 5A systems (interchangeable)
Tape types:	Thick, thin
Playback speeds:	80 ips, 160 ips (thin tapes); 135 ips, 270 ips (thick tapes) up to 1024 Mbit/s (Mark 5A)
Formats:	Mark III/Mark IV/VLBA (Mark IV/VLBA w/wo barrel roll, data demod.)
Sampling:	One bit; two bit
Fan-out:	1:1 1:2 1:4
Fan-in:	Not supported
No. channels:	$\leq$ 16 USB and/or LSB
Bandwidth/channel:	(2, 4, 8, 16) MHz
Signal:	Mono, dual frequency; dual polarization
Modes:	128-16-1 128-16-2 128-8-1 128-8-2 128-4-1 128-4-2 128-2-2 256-16-1 256-16-2 256-8-1 256-8-2 256-4-2 512-16-2 512-8-2 1024-16-2
Correlation	
Geometric Model:	CALC 8
Number of boards:	16
Phase cal:	Single tone extraction at selectable frequency
Pre-average times:	0.2 s to 5 s
Lags per channel:	32 minimum, 2048 maximum; 1024 tested and used
Maximum output:	9 stations: 36 baselines, 16 channels, 32 lags with autocorrelation function (ACF) without circular polarization (CP); 8 stations: 28 baselines, 16 channels, 32 lags with ACF with CP
Fringe-fit:	Off-line FOURFIT run
Export:	Data base, MK4IN to AIPS

The correlator is controlled from a dedicated workstation. Correlation setup, data inspection, fringe-fitting, and data export are done with a separate workstation. Per year about 300 Gbyte to 400 Gbyte of correlated data are generated. The total disk space available for data handling at the correlator is 1000 Gbyte. Data security is guaranteed by using a file system with redundancy (RAID level 5) and by daily back-up of the data on a 120 Gbyte disk of a low-end Linux PC.

3. Staff

The people in the geodetic group at the Bonn correlator are

- Arno Müskens: group leader, overall experiment supervision, scheduling of T2, OHIG and EURO series.
- Alessandra Bertarini: experiment setup and evaluation of correlated data, media shipping.
- Alexandra Höfer: experiment setup and evaluation of correlated data, media shipping.
- 10 student operators for the night shifts and the weekends.

MPIfR staff supports IVS correlation with

- Walter Alef: correlator manager, correlator software maintenance and upgrades, and computer system administration.
- David Graham: technical development, consultant.
- Heinz Fuchs: correlator operator, responsible for the correlator operator schedule, daily operations, and tape shipping.
- Hermann Sturm: correlator operator, correlator support software, tape shipping.
- Michael Wunderlich: engineer, correlator and playback drive maintenance, Mark 5 support.
- Rolf Märtens: technician, playback drive maintenance, Mark 5 support.

4. Status

In 2004 the Bonn group correlated and released 50 geodetic experiments: 10 T2, 29 R1, four EURO, five OHIG, the NORD01 experiment and the VIEPR1 experiment (diploma thesis project).

To improve the monitoring of the Terrestrial Reference Frame (TRF), the IVS Observing Program Committee (OPC) decided to enlarge the T2 sessions to as many as 16 stations (for more details see the IVS Newsletter, Aug. 2004, p. 6).

The geodetic group tested ftp-VLBI between Kashima and TIGO. A piece of an IVS-T2026 scan was transferred to the Bonn FTP server from Kashima via Haystack and from TIGO, copied onto Mark 5 modules and was succesfully correlated. Ftp-VLBI was used on subsequent occasion and fringes were always found.

The astronomical group correlated a 1 Gbit/s observation with eight stations simultaneously. The processing factor (PF, ratio between the correlation time and the observation time) for this 1 Gbit/s experiment was better than 1.5. It was a Mark 5 only observation with short scans.

5. Outlook for 2005

In spring we expect to have Gbit/s connectivity to BonnNet and into Géant (European Academic Network). We will be limited initially by the 100 Mbit/s router at MPIfR. This will be upgraded to higher bit rates depending on the demand. A proposal to participate in the German 10 Gbit/s optically-switched test network VIOLA[4] has been submitted.

[4](http://www.dfn.de/content/entwicklungen/netztechnik/optischenetze/)

MPIfR and BKG will upgrade the correlator to 12 stations with Mark 5B, including new computers and a software upgrade.

The tape drivers and station units will still be mantained for some time because not all IVS and VLBA stations have been upgraded to Mark 5, though the upgrade of the VLBA to Mark 5A has begun thanks to the Huygens mission.

Haystack Observatory VLBI Correlator

Mike Titus, Roger Cappallo, Brian Corey, Arthur Niell, Alan Whitney

Abstract

This report presents the status of the Haystack Correlator, focusing on the activities, current and future hardware capabilities, and staff.

Figure 1. Partial view of the Haystack Mark IV correlator, showing 1 rack containing 4 Mark 5A units and a decoder, correlator rack, 2 tape units and 1 rack containing 4 station units.

1. Introduction

The Mark IV VLBI correlator of the MIT Haystack Observatory, located in Westford, Massachusetts, is supported by the NASA Space Geodesy Program. Production correlator time is dedicated to processing geodetic VLBI observations for the IVS. In addition to its role as an operational processor, the Haystack Correlator also serves as a development system for testing new correlation modes, e-VLBI, hardware improvements, and for diagnosing correlator problems encountered at Haystack or at one of the identical correlators at the U.S. Naval Observatory and the Max Planck Institute for Radioastronomy. This flexibility is made possible by the presence on-site of the team that designed the correlator hardware and software.

2. Summary of Activities

There has been a diverse array of activities over the last year. Some of the highlights of our activities follow.

A major focus continues to be improving and expanding the e-VLBI technique. Many experiments and tests have been performed, including the correlation of data in real time at rates up to 512 Mb/sec, as well as a demonstration for a major supercomputing conference. Tangentially related to operations is the continuing effort to transfer station data via e-VLBI for regular sessions, thus circumventing the process of shipping physical media. For more detailed information on correlator related e-VLBI development activities at Haystack, please refer to the "Haystack Observatory Technology Development Center" report.

Integration of Mark 5 into operations continues. Four Mark 5 units were installed in a single rack, and a tape drive was removed from the correlator line of equipment to make room for it. New Mark 5A software releases are frequently tested on the Haystack system before general release.

Increased efficiency due to Mark 5 and other improvements has allowed the use of production time to examine parameter space not previously explored in order to investigate whether any errors - systematic or otherwise - are being inadvertently introduced into results. Several tests have been run in order to examine issues such as effects near search range edges, consistency of results in repeat processings, and the like. Many of these studies are in their early stages, and we hope to report the results later in 2005.

New observing modes, apart from e-VLBI, such as Gb/sec recording, have been tested and used extensively in the year's production sessions. The geo_export package has been upgraded in order to accommodate these new observing modes.

3. Experiments done

Since January 2004, 47 geodetic VLBI experiments have been processed at the Haystack correlator. This total subdivides into 13 R1s, 9 R&Ds, 1 APSG, and 24 test experiments. The test experiments cover an assortment of e-VLBI, new observing modes, Mark 5, correlator software, and station/equipment tests.

4. Current/Future Hardware and Capabilities

Currently, functional hardware installed on the system includes 6 tape units, 5 Mark 5A units, 7 station units, 16 operational correlator boards, 2 crates, and miscellaneous other support hardware. We have the capacity to process all baselines for 7 stations simultaneously in the standard geodetic modes. By mid 2005, implementation of the Mark 5B may allow the correlation of more than 7 stations, due to the Mark 5B's independence of an accompanying station unit. We expect to remove tape drives from the system as more stations move to recording exclusively on a Mark 5.

5. Staff

There have been a number of staff changes in the last year. Due to increased efficiency and the ending of the CMVA project, we have reduced the number of hours of production. One of our long-time operators, Ellen Cellini, has moved on to a new career, and we decided not to fill her position. This leaves us with 30 hours per week of production time. The last few months of operation in this mode has proven adequate to meet our production deadlines. Another change is that Brian Corey is now working remotely from Florida, supplemented by bi-monthly local visits. Thanks to high speed internet access, this arrangement manages to work almost as well as locally-based operations. Further changes are that David Lapsley has left for industry—with Jason SooHoo taking up part of the e-VLBI effort in his place—and the retirement of our long-time maintenance person, Tom Buretta.

Staff who participate in aspects of Mark IV development and operations include:

5.1. Software Development Team

- John Ball - operator interface; playback; Mark 5/e-VLBI development
- Roger Cappallo - leader; system integration; post processing
- Kevin Dudevoir - correlation; maintenance/support; e-VLBI development
- Jason SooHoo - e-VLBI development
- Alan Whitney - system architecture; Mark 5/e-VLBI development

5.2. Operations Team

- Peter Bolis - correlator maintenance
- Brian Corey - experiment correlation oversight; station evaluation; technique development
- Dave Fields - playback drive maintenance; Mark 5 installation/maintenance
- Glenn Millson - correlator operator
- Arthur Niell - technique development
- Don Sousa - correlator operator; experiment setup; tape library and shipping
- Mike Titus - correlator operations oversight; experiment setup; computer services; software & hardware testing
- Ken Wilson - correlator maintenance; playback drive maintenance

6. Conclusion/Outlook

We hope to begin operational testing of Mark 5B in the next year. Each Mark 5B that is integrated will allow either the retirement of a station unit, or an increase in the number of stations that can be simultaneously correlated. The station units have been a major source of reduced efficiency due to frequent need for reprocessing and to the length of time they take to set up each scan. This upgrade, and the greater use of Mark 5 and e-VLBI in operations, should continue to increase the efficiency and reliability of operations. We will also concentrate on moving operational correlator production tasks to more modern Linux-based systems over the next year, possibly including the correlator run time software. All the above should speed up and streamline the data production process and provide greater capability to the IVS community.

IAA Correlator Center

Igor Surkis, Yuriy Rusinov, Violetta Shantir, Vladimir Zimovsky

Abstract

Development of the new correlator MicroPARSEC was continued in 2004. Some experiments were carried out on the single unit MicroPARSEC. The development of the new correlator was continued. This correlator will be based on many MicroPARSEC devices. The old correlator TISS-1M was maintained.

1. Introduction

The correlator MicroPARSEC was developed in 2002-2003. It can be directly connected to the Canadian playback terminal S2-PT. This device can process two frequency channels with bandwidth of 16 MHz under 1- or 2- bit sampling conditions. It has 64 complex delays in every frequency channel. MicroPARSEC was developed as PCI plate for IBM PC.

The development of the control computer software and the programmable MicroPARSEC microchip algorithms were continued in 2004. Now MicroPARSEC can be used as two-channel correlator and spectral analyzer. We also continued the development of the new multistation, multichannel correlator. It will consist of a set of MicroPARSEC units, inserted into some computers and synchronized in a local network.

The correlator TISS-1M was also operated in 2004. This multistation, multichannel unit was developed in 1988-1993. It can process 2 MHz bandwidth channels. During 2004 this correlator was used to process tapes of previous observations and for MicroPARSEC testing.

2. Using MicroPARSEC as Spectral Analyzer

MicroPARSEC can be used for spectral analysis. High resolution spectra can be obtained using special control computer software under stable signal conditions. It can be achieved by processing the autocorrelation function at different parts and in different time periods. The example of this spectrum with resolution 244.1 Hz from 2 MHz bandwidth is presented in Figure 1 (observations of the source W3OH at station Svetloe, under 1.35 cm wave).

Also MicroPARSEC can be used as mobile spectral analyzer. In particular it was used so during the experiment 01/29/2005 at Svetloe. The S2-RT recording terminal was connected to the Mark IV video converter through sampling device developed at IAA RAS. The MicroPARSEC got data through S2-RT and made spectral analysis. The experiment was controlled in this way. In particular, picosecond generator level presented on the obtained spectrum can be controlled.

3. Usage MicroPARSEC Device for Crosscorrelation Process

Two channel observations were processed by crosscorrelation technique through MicroPARSEC correlator. Example of obtained power spectrum is shown at Figure 2. The source 0552+398 was observed on the baseline Svetloe-Zelenchukskaya at 01/30/2005 1:30:00 on reference frequency 8232.99 MHz with 2 MHz bandwidth, accumulation period 0.5 seconds, and accumulation time 128 seconds.

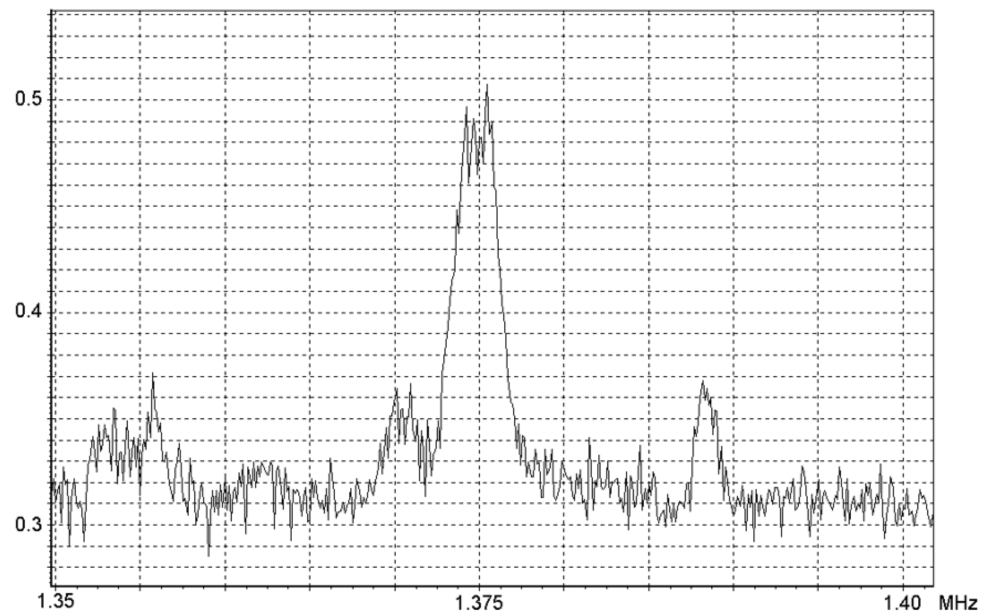

Figure 1. Spectrum of the source W3OH, wave 1.35 cm, station Svetloe. The fragment of spectral is shown, y-axis has conventional units

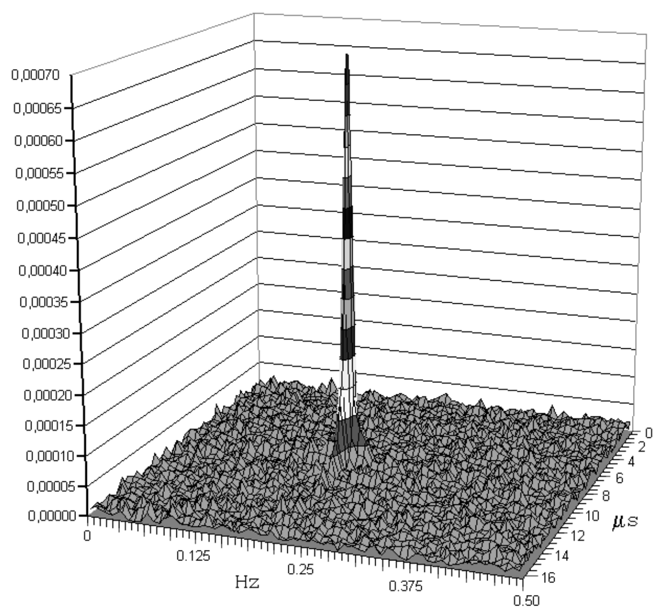

Figure 2. Power spectrum of source 0552+398, baseline Svetloe-Zelenchukskaya at 01/30/2005 1:30:00

4. The New Correlator Project by Using the Set of MicroPARSEC Units

At first it was planned to use MicroPARSEC devices for test purposes only. It was assumed to process some experiments through MicroPARSEC and develop new similar devices with 16 frequency channels and manufactured as CompactPCI U6 plates. But there were too many technical problems and this project was frozen.

Currently correlation based on MicroPARSEC devices inserted into some IPM PC (4-6 MicroPARSEC plates in every computer) is under development. 21 MicroPARSEC plate and 4-6 computers are needed for 3-station, 14-channel correlator. Scheme of such correlator is shown in Figure 3. MicroPARSEC plates are connected to the playback terminals through special base commutation device. Synchronization between computers and playback terminals is realized by local network. The operator can fully control the whole correlator from one of the computers.

At first the S2-PT will be used as playback system. Finally Mark 5A playbacks will be used. The development of the special coupling devices to use Mark 5A terminals with MicroPARSECs is required.

We suppose to produce new correlator during 2005-2006.

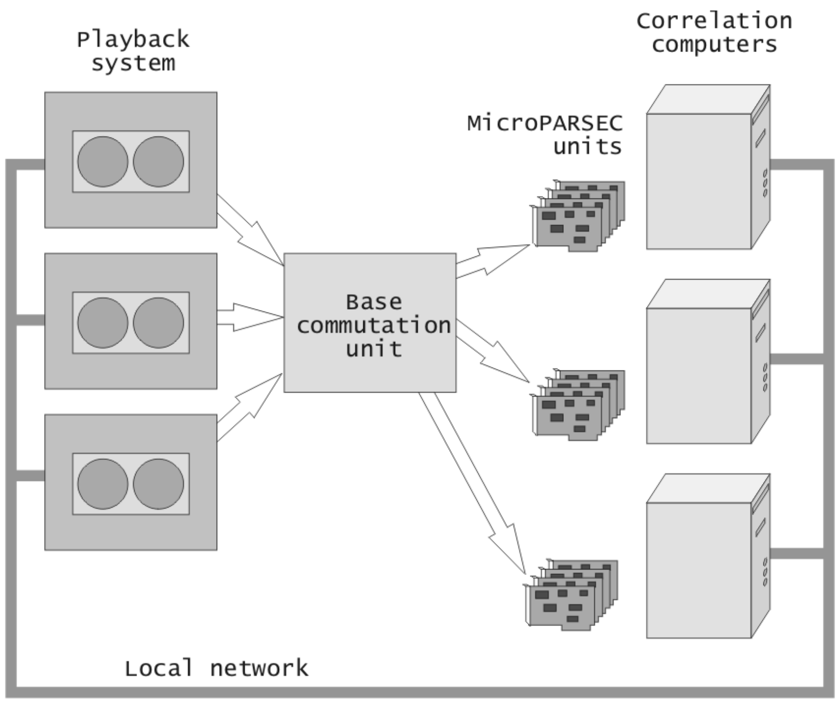

Figure 3. The new correlators scheme

5. Staff

- Dmitriy Plotnikov — hardware development, plate design, microchips programs
- Yuriy Rusinov — software development, correlator operator
- Violetta Shantir — software development, post processing
- Igor Surkis — principle investigator, system integration, software development
- Vladimir Zimovsky — software development, system integration, correlator operator

6. Conclusion

The development of the new generation correlator based on the MicroPARSEC units allows to process full volume VLBI data.

The old correlator TISS-1M will be used until putting into operation the new correlator.

VLBI Correlators in Kashima

Mamoru Sekido, Yasuhiro Koyama, Moritaka Kimura, Hiroshi Takeuchi

Abstract

Correlators at Kashima have been used for processing of experimental VLBI observations. The KSP correlation system has been used for domestic VLBI observations for geodesy in 2004. Instead of the decreasing frequency of using those hardware correlators, occasions to use disk-based recording system (K5) are getting more frequent. Two different disk-based recording systems have been developed. One is a multi-channel VLBI system named K5/VSSP and the other is a single channel Giga-bit system called K5/VSI. Data recorded with either of these disk-based recording system are processed by software correlators. The correlation processing rate with software correlator is already in the range of practical use.

1. General Information

Kashima Space Research Center of National Institute of Information and Communications Technology (NICT; formerly Communications Research Laboratory) has developed VLBI hardware correlators as IVS technical development center. Now the field of technology development in correlation processing is shifting from hardware to software owing to quick growth of computing power of personal computers. A software correlator has great benefit for VLBI community in several points of view. (1) It has wide flexibility in configuration of the specification. The lag number and frequency resolution can be modified very easily. (2) Also the cost of maintenance and bug fixing is lower. (3) Multiplication of the quantity of correlator is enabled simply by purchasing additional personal computers and by copying the software. (4) It is good from an educational point of view and for the expansion of the VLBI community to universities, since correlator software can be written by university students, giving experience in correlation processing. Actually, some universities in Japan have started to work for VLBI data processing with IP-sampler board, which is 4ch sampler component of K5 system.

By the way, we are still going to operate hardware correlators for processing the data recorded on conventional tape-based systems. Here we introduce our VLBI correlators and our activity in the development of correlation processing software.

2. Correlators

2.1. KSP-Correlation System

The JADE series VLBI experiments are omni-bus type geodetic VLBI service coordinated by the GSI of Japan. The 11m antenna at Gifu University, 32m Yamaguchi University, and 34m Uchinoura and 64m Usuda deep space tracking stations of ISAS/JAXA have participated in some of those experiments to determine their terrestrial coordinates. Data processing of JADE experiments is sometimes shared with GSI-correlators and the KSP correlators in Kashima. Correlation processing was performed on JADE0403, JADE0404, and JADE0407 experiments to process the data on GIFU-11m antenna related baselines. Also two VLBI experiments for ionospheric TEC measurements, in which Kashima-34m, Gifu-11m, and Mizusawa-20m antennas participated, were processed with the KSP correlator.

Figure 1. KSP Correlator room. The KSP hardware-correlation system, which is capable of processing 4 stations and 6 baselines of tape-based VLBI data, is sometimes operated for domestic geodetic VLBI data processing.

2.2. Software Correlation System

2.2.1. K5/VSSP Correlation System

Correlation process of the K5/VSSP disk-based recording system is performed by a software-correlation package for geodesy, which has been developed by Kondo (Kondo et al. 2003). It runs on standard personal computer (PC) and performs correlation of two data sets of VLBI data in the form of binary files on hard disk (HD). Figure 2 shows the K5/VSSP system, the K5/VSI system is described in the next paragraph. The K5/VSSP system is used for e-VLBI experiment

Figure 2. K5/VSSP VLBI system (right in the left panel) consists of 4 PCs. Each PC is equipped with one IP-sampler board, which has 4 channels of data input. Sampled data are recorded on their HDs as binary files. The maximum recording rate is 128 Mbps per PC. These recording PCs are also used for data processing purposes as correlators. K5/VSI VLBI system (left in the left panel) has capability of 1 Gbps recording rate per PC. Its data is fed from Giga-bits sampler (right) in VSI format.

for rapid UT measurements (Koyama et al. 2003, Koyama et al. 2004). The processing speed of the K5/VSSP software correlator is typically 2 Msps/CPU with Pentium III processor. This software correlator package is also used at JIVE for quick fringe detection before observations with the EVN.

2.2.2. K5/VSI system

The K5/VSI system consists of a data recording interface board equipped in a PC with RAID-HD system (Figure 2 left) and Giga-bit sampler with VSI output. The K5/VSI system is going to be used for the Huygens VLBI observation in collaboration with EVN, VLBA, ATNF, and Chinese VLBI institutions. Specified frequency channels of data are extracted from the data records by using a digital filtering technique (Takeuchi et al. 2004), and it is converted to Mark 5 data.

Kimura has developed ultra high-speed correlation software for the K5/VSI. Its processing rate is 0.5 Gsps/PC with PowerPC 970FX(2GHz) processor at present. The rate is limited by data transfer speed of LAN, which connects the K5/VSI. A peer-to-peer cross correlation processing scheme, by which the processing rate can be made independent of the number of baselines, was proposed (Kimura 2002). Processing rate of the software correlator as a function of FFT points is displayed in Figure 3.

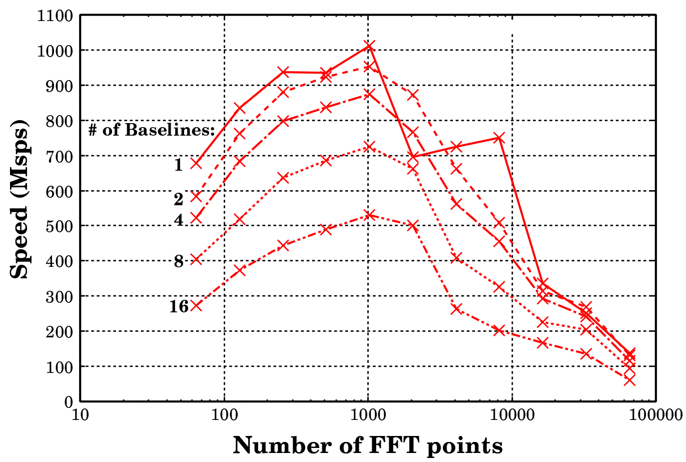

Figure 3. Processing rate of ultra-high-speed FX-type software correlator is plotted as a function of number of FFT points. The first rise of plot along the x-axis is due to increasing efficiency in data transfer from disk to the CPU. The drop of efficiency in the second half along the x-axis is due to shortage of cache memory in the CPU.

2.2.3. Other Software Correlators

Correlation processing of VLBI data of spacecraft signal is slightly different from the standard one at least at two points. Firstly, curvature of the wavefront has to be taken into account in the delay model, since the distance from the baseline to the spacecraft is at finite distance. For this purpose, a newly developed a priori delay model (Sekido & Fukushima 2003, 2004) is implemented and used for a priori delay computation. Secondly, because a modulated signal with limited bandwidth is transmitted from the spacecraft, correlation processing with spectral frequency filtering may be effective to enhance the SNR. Thus filtered correlation process is applied for post-correlation data for extraction of group delay. When phase delay is used for spacecraft navigation, extraction of Fourier component of the carrier signal with high frequency resolution is the main task to be done in the processing. For this purpose, a special correlation package for phase delay extraction was developed.

A realization of distributed correlation processing system is in progress. One is a client-server system working on unix system, in which dedicated client computers are deployed. Currently it is realized by using remote-shell. Another is screen-saver mode processing system named "VLBI@home". The latter one is based on the idea that most time of PC resource are idle. Actually, these distributed correlation systems were used in a Japan-US e-VLBI experiment and supported the rapid UT1 estimation in 4.5 hours.

3. Staff

- Tetsuro Kondo is responsible for overall operations and performance. He is also developing software correlators for geodetic purposes.
- Yasuhiro Koyama is in charge of correlation processing system and is working on e-VLBI on intercontinental baseline.
- Mamoru Sekido is in charge of KSP correlation system and is working on VLBI applications for spacecraft navigation.
- Moritaka Kimura is working on the development of a hardware Giga-bit correlator and a high speed Giga bit software correlator.
- Hiroshi Takeuchi is working on software digital filter and the next generation high speed sampler.

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Tsukuba VLBI Correlator

Morito Machida, Masayoshi Ishimoto, Shinobu Kurihara, Kazuhiro Takashima

Abstract

This is a report of the activities at the Tsukuba VLBI Correlator in 2004.

1. General Information

The Tsukuba VLBI Correlator, as well as the Tsukuba 32-m VLBI station, was established by the Geographical Survey Institute (GSI), at the GSI site located in Tsukuba city, Ibaraki, Japan. The Correlator routinely processes geodetic VLBI sessions in local range named JADE (Japanese Dynamic Earth observation by VLBI) and UT1 Intensive sessions between Wettzell and Tsukuba. The correlator is preparing for introducing a disk-based K5 system in addition to its existing tape-based K4 system.

2. Component Description

The Tsukuba VLBI Correlator basically operated with the tape-based K4 correlation system for geodetic VLBI that was designed and developed by CRL (now NICT). The K4 correlation system mainly has the following 4 components: 3 correlator units with 32 lags for each 16 channels, a system controller, 3 tape drive units housed in auto tape changers, and an HP workstation. The system uses the correlation processing software "Oxtail Version 2.0" and the analysis software "CALC/SOLVE (NASA/GSFC)".

In 2004, we had a plan to upgrade our correlator to the disk-based K5 correlation system. Although integration of the K5 system has not been completed yet, the following hardware has been introduced into the new system as an initial step: 24 PCs, each ready for externally mounting 4 K5 disks via interface boards, 8 rack mount correlation servers with dual CPUs (Fig.1). Kernel programs of the system have been introduced under license from a developer of the programs, National Institute of Information and Communications Technology (NICT), based on an agreement of research cooperation between NICT and GSI. All four GSI network stations also introduced the K5 recording system in March. A few parallel sessions recorded on K5 and K4 were conducted, but the amount of K5 data was not enough for comparisons with results from K4. Completing integration of K5 requires more parallel observations for resolving this problem. To deal with increasing data volumes from the parallel observations, 3 correlation units and a recorder interface unit that NICT lent us were added on the K4 system in June. This improvement increased the K4 processing capacity from "3 baselines for 3 stations" to "6 baselines for 4 stations".

3. Global Solution

GSI, not the IVS analysis center, independently continued global analyses for determining positions/velocities of the local VLBI stations in Japan. We worked on it on a quarterly basis in 2004, and the latest version of the global solution was "gsi2004d" released December 2004, in which 3888 data from most of the 24-hour sessions between April 1980 and December 2004 were adopted.

Figure 1. K-5 correlator system (in preparation)

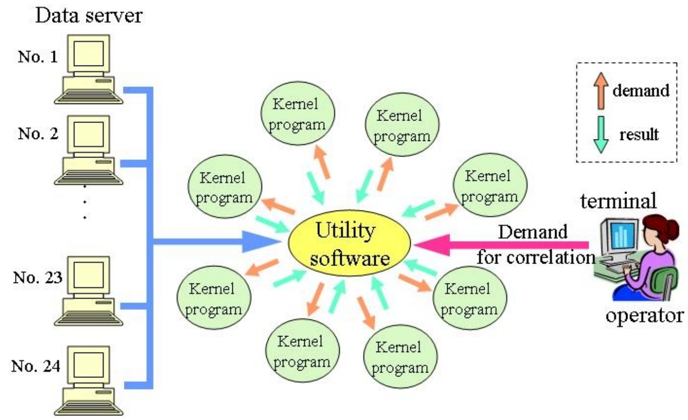

Figure 2. utility software (in preparation)

Table 1 shows the site coordinates as an example for the parameters obtained in the solution. Most of the sites were determined with few mm precision. 148 station positions/velocities were estimated in the analysis as global parameters. Station positions were given at epoch 1997.01.01. The EOPs (x, y pole coordinates, UT1-TAI, nutation offsets) were estimated as local (each session) parameters.

Table 1. Station position from gsi2004d

station	X [m]/sigma	Y [m]/sigma	Z [m]/sigma	session
TSUKUB32	-3957408.776	3310229.386	3737494.810	201
	0.001	0.001	0.001	
SINTOTU3	-3642142.082	2861496.673	4370361.834	31
	0.004	0.003	0.004	
AIRA	-3530219.323	4118797.579	3344015.865	42
	0.003	0.003	0.002	
CHICHI10	-4490618.492	3483908.175	2884899.141	43
	0.003	0.003	0.002	
VERAMZSW	-3857241.857	3108784.796	4003900.611	8
	0.012	0.010	0.012	
GIFU11	-3787123.407	3564181.781	3680275.138	15
	0.005	0.005	0.005	

4. Staff

The staff members of the Tsukuba VLBI Correlator are compiled in the following list. The other staff members of the GSI VLBI team are listed in a table of the Network Station report of the Tsukuba 32-m VLBI station (this volume). The staff of Space Engineering Development Co., Ltd (SED) mainly performed routine operations over 200 days under contract with GSI. Additional 24 days were funded by National Astronomical Observatory of Japan (NAOJ).

- K. Takashima : Operation manager (GSI)
- M. Machida : technical staff, correlation chief, K4 tape librarian (GSI)
- M. Ishimoto : technical staff, intensive set-up (GSI)
- S. Kurihara : technical staff, global solution analyst (GSI)
- K. Sakamoto : main operator in routine correlation processing (Space Engineering Development Co., Ltd)
- T. Nishino : sub operator in routine correlation processing (Space Engineering Development Co., Ltd)

5. Current Status and Activities

The Tsukuba VLBI Correlator processed the following in 2004: 12 domestic 24-hour sessions for geodetic VLBI campaign (project JADE; Japanese Dynamic Earth observation by VLBI), 55 Intensive sessions for UT1, 10 Syowa sessions, some fringe tests.

GSI conducted 24-hour JADE sessions once a month in response to increased demand for geodetic observation. The participants in JADE sessions were not only the GSI network stations, but the other ones including VERAMZSW and GIFU11. JADE was expected especially by NAOJ as a basis for determining the antenna position of VERAMZSW, one of the astrometric VLBI stations in the VERA project promoted by NAOJ. We needed to process each JADE session twice to complete all, because the capacity of our K4 correlator was not enough to process all the participating stations at once in the case of more than five stations. Consequently, we had submitted the processed data twice per session to the MarkIII database in previous years. In 2004, we changed our policy about this flow of submission and have submitted processd databases only once per session after having all baselines processed. Currently, 4 JADE sessions have not been completed yet: JADE-0407, JADE-0410, JADE-0411 and JADE-0412. These sessions have already been processed in 6 baselines for 4 stations, but are missing the second processing for the GIFU11 baselines.

Providing feedback to stations was encouraged as one of the main tasks. In JADE-0408, Pcal was corrupted badly at CHICHI10. The suspected causes of the problem were RF, LNA, cable connection, and IF attenuator. Carefully monitoring CHICHI10 during JADE-0409, Pcal remained corrupted. In addition, there was a gross error of cable value with elevation angle less than 40 degrees. Through the ensuing investigation, the cause turned out to be a cable interrupted around antenna elevation axis. The cable was fixed shortly before JADE-0410.

Corrupted Pcals with poor level of less than 1 percent were frequently detected at TSUKUB32 in correlation processing. In each case, manual phase cal procedure was necessary to apply in fringe fitting. We suspected a base station for commercial cellular phones in the neighborhood of TSUKUBA32 as a radio interference source. However this problem was resolved when we changed formatters at TSUKUB32 in December. The pcal level was improved up to 3 percent and no manual pcal was required after the replacement.

The Tsukuba VLBI Correlator performed correlation processings of Syowa sessions. Because the Syowa sessions were recorded on two different systems, S2 recording system at Hobart and

HartRAO and K4 recording system at Syowa, copying S2 to K4 had to be done at Mitaka Correlator before processing.

The correlator also processed 55 Intensive sessions which were observed on the single baseline between TSUKUB32 and WETTZELL. The intensive sessions performed by the end of July had been recorded and processed on K4 as usual. From August through December, there were two changes in running the Intensive sessions: 1) It was carried out also on Sunday adding to the existing Saturday sessions. 2) As one of our challenges in the field of e-VLBI, sessions on last Sunday of month were with our new disk-based system. In the e-VLBI sessions, data had been recorded on K5 at TSUKUB32 and on Mark 5 at WETTZELL. The data recorded at WETTZELL were transferred to the Tsukuba VLBI Correlator via Internet and then converted to K5 in order to perform correlation processing. We have achieved 2 days in one session data processing: 1 day for data transfer, 1 day for correlation processing.

The Tsukuba VLBI Correlator has presented its detailed current status and activities at the VLBI community in Japan ([1],[2]).

6. Plan for 2005

In 2005, the Tsukuba VLBI Correlator is expected to be responsible for processing 12 domestic 24-hour sessions of the project JADE conducted by GSI. It is also planned to process the TSUKUB32/WETTZELL Intensive sessions on the K5 system starting in April; the sessions are performed on both Saturday and Sunday with K5/Mark 5 system.

We intend to work on integrating our K5 correlation system as well as upgrading and expanding our K-5 hardware, aiming to entirely shift from K4 system. Especially, developing and testing our K5 utility software to handle kernel programs of NICT (Fig.2) is a priority during early part of 2005.

The K4 correlator facility will be kept at least until March 2006 even after the GSI network stations entirely shift to K-5 mode.

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Washington Correlator

Kerry A. Kingham

Abstract

This report summarizes the activities of the Washington Correlator for the year 2004. The Washington Correlator provides up to 136 hours of processing per week, primarily supporting Earth Orientation and astrometric observations. In 2004 the major programs supported include the IVS-R4, IVS-INT, IVS-R1, IVS-T and CRF and CRFD experiments. Two Mark 5 playbacks were added bringing the total at the correlator to 8.

1. Introduction

The Washington Correlator (WACO) is located at and staffed by the U. S. Naval Observatory (USNO) in Washington, DC, USA. The correlator is sponsored and funded by the National Earth Orientation Service (NEOS) which is a joint effort of the USNO and NASA. Dedicated to processing geodetic and astrometric VLBI observations, the facility spent 100 percent of its time on these experiments. All of the weekly IVS-R4 sessions, all of the daily intensives, and several IVS-R1 sessions were processed at WACO. The remaining time was spent on terrestrial reference frame and astrometry sessions. The facility houses a Mark IV Correlator.

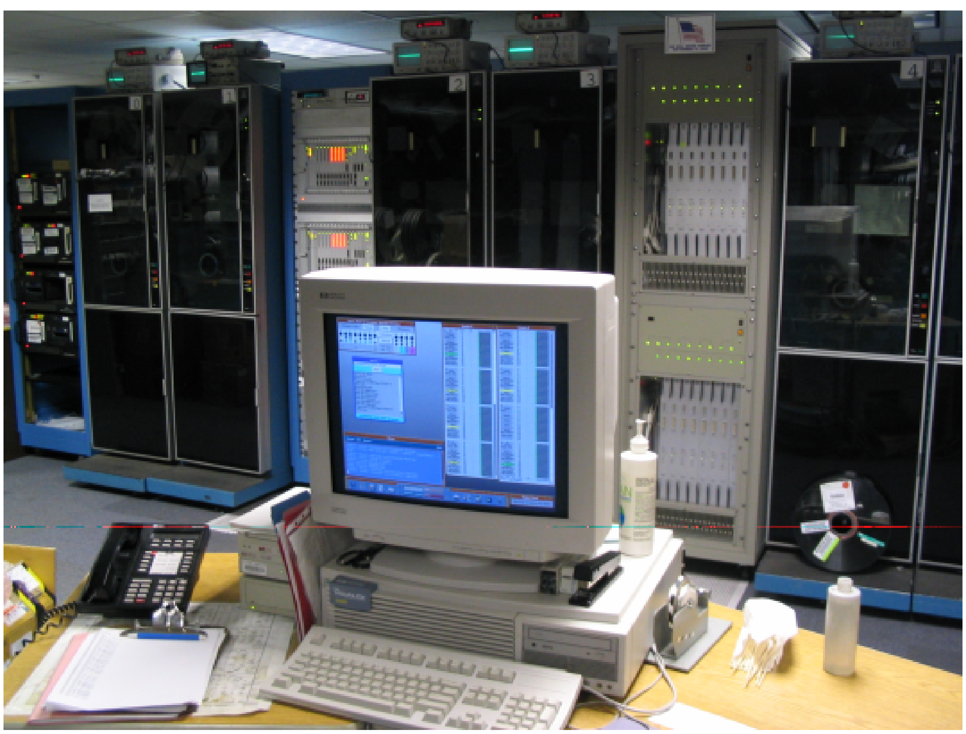


Figure 1. The left half of WACO showing 4 Mark 5A units (left), tape drives, the operator's console, and the central processor (right).

2. Correlator Operations

Early in 2004, the Washington Correlator added 2 Mark 5A units bringing the total at the correlator to 8. This is the maximum number of playback units that can be used by the correlator until the Mark 5B systems and correlator interfaces are available. In addition, two Mark 5As were loaned to the Haystack Correlator, and one was sent to Algonquin. An additional 90 "A" diskpacks were purchased to support IVS programs.

The Washington Correlator also assisted several stations by rapidly, and thoroughly checking their initial Mark 5 recordings to confirm proper installation and operation. While there were a few startup problems requiring additional diagnostics, all of the stations should be congratulated on their rapid and mostly trouble–free conversion to Mark 5 operation. Due to this rapid conversion to mostly Mark 5 recordings, the processing factor for R4 experiments averaged about 1.25, down from 1.5 in 2003.

A highlight of the year was the processing of a 16–station TRF experiment (T2028). This was one of the first 16–station geodetic experiments done on a Mark IV Correlator and many minor problems had to be circumvented. The management of this large experiment was a challenge as well! Overall, the processing went very well, if not the ultimate in efficiency, and proved that large experiments could be processed at the Mark IV correlators without either causing problems to the IVS program or taking an extraordinary amount of correlator resources.

The correlator facility operates up to 136 hours per week.

Table 1 lists the experiments processed during 2004.

Table 1. Experiments processed during 2004

51	IVS-R4 experiments
16	CRF (Celestial Reference Frame)
13	IVS-R1
1	APSG (Asia Pacific)
3	IVS-T (Terrestrial Reference Frame)
199	Intensives

3. Staff

The Washington Correlator is under the management and scientific direction of the Earth Orientation Department of the U.S. Naval Observatory. USNO personnel continue to be responsible for overseeing the scheduling and processing. During the period covered by this report, a private contractor, NVI, Inc., supplied a contract manager and correlator operators. Table 2 lists staff and their duties.

Table 2. Staff

Staff	**Duties**
Dr. Kerry Kingham (USNO)	VLBI Correlator Project Scientist
Bruce Thornton (NVI)	Operations Manager
Harvis Macon (NVI)	Lead Correlator operator
Roxanne Inniss(NVI)	Tape Librarian
Dwayne Sneed (NVI)	Correlator Operator
Joseph Granderson (NVI)	Correlator Operator
Kenneth Potts (NVI)	Correlator Operator
Steven Springer (NVI)	Part-time Correlator Operator
Lawrence Dorsey (NVI)	Part-time Correlator Operator
Valerie Bockarie (NVI)	Part-time Correlator Operator

4. Outlook

The Washington Correlator plans to upgrade the Mark 5A playbacks to Mark 5B coordinated with the installation of Mark 5Bs at the Network Stations. Processing of 1 Gb/sec experiments awaits the testing of the correlator at the 1 Gb/sec bandwidth.

Data Centers

BKG Data Center

Volkmar Thorandt, Reiner Wojdziak

Abstract

This report summarizes the activities and background information of the IVS Data Center for the year 2004. Included are information about functions, structure, technical equipment and staff members of the BKG Data Center.

1. BKG Data Center Functions

The BKG (Federal Agency for Cartography and Geodesy) Data Center is one of the three IVS Primary Data Centers. It archives all VLBI related data of IVS components and provides public access for the community. The BKG Data Center is connected to the OPAR and CDDIS Data Centers by mirroring the OPAR and the CDDIS file stocks several times per day. The following sketch shows the principle of mirroring:

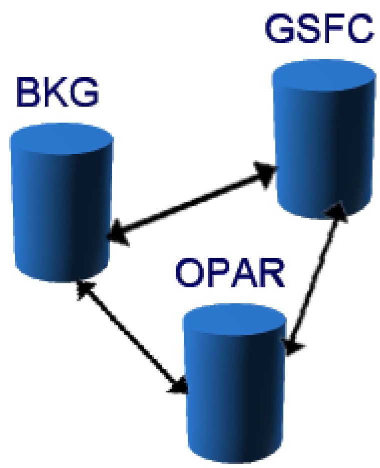


Figure 1. **Principle of mirroring**

IVS components can choose one of these Data Centers to put their data into the IVS network by using its incoming area which each of them has at its disposal. The BKG incoming area is protected and the users need to obtain username and password to get access (please contact the Data Center staff).

An incoming script is watching this incoming area and checking the syntax of the files sent by IVS components. If it is o.k. the script moves the files into the data center directories; otherwise the files will be sent to a badfile area. Furthermore the incoming script informs the responsible staff at Data Center by sending e-mails about its activities. The incoming script is part of a technological unit which is responsible for managing the IVS and the Operational Data Center and to carry out first analysis steps in an automatic manner. All activities are monitored to guarantee data consistency and to control all analysis steps from data incoming to delivering of analysis products to IVS.

Public access to the BKG Data Center is available through FTP:

```
ftp.leipzig.ifag.de
uid: anonymous
pw: e-mail address
cd vlbi
```

respectively

```
WWW:              http://www.leipzig.ifag.de/VLBI
```

Structure of BKG IVS Data Center:

```
vlbi/            : root directory
ivs-iers/        : VLBI products for IERS
ivs-pilot2000/   : directory for special investigations
ivs-pilot2001/   : directory for special investigations
ivs-pilotbl/     : directory for baseline time series
ivs-pilottro/    : directory for tropospheric time series
ivscontrol/      : controlfiles for the data center
ivscontrol_new/  : temporary test directory
ivscontrol_old/  : temporary test directory
ivsdata/         : VLBI observation files
ivsdocuments/    : IVS documents
ivsproducts/     : analysis products
                   (earth orientation, terrestrial and celestial frames,
                    troposphere, daily sinex files)
```

2. Technical Equipment

HP Workstation (HP UX B11.23 U a 64 operating system)
disk space: 190 GBytes (Raid system)
internet rate: 34 MBit/sec
backup: automatic tape library

3. Staff Members

Volkmar Thorandt (coordination, data analysis, data center, volkmar.thorandt@bkg.bund.de)
Reiner Wojdziak (data center, web design, reiner.wojdziak@bkg.bund.de)
Dieter Ullrich (data analysis, data center, dieter.ullrich@bkg.bund.de)
Gerald Engelhardt (data analysis, gerald.engelhardt@bkg.bund.de)

CDDIS Data Center Summary for the 2004 IVS Annual Report

Carey Noll

Abstract

This report summarizes activities during the year 2004 and future plans of the Crustal Dynamics Data Information System (CDDIS) with respect to the International VLBI Service for Geodesy and Astrometry (IVS). Included in this report are background information about the CDDIS, the computer architecture, staffing supporting the system, archive contents, and future plans for the CDDIS within the IVS.

1. Introduction

The Crustal Dynamics Data Information System (CDDIS) has supported the archive and distribution of Very Long Baseline Interferometry (VLBI) data since its inception in 1982. The CDDIS is a central facility providing users access to raw and analyzed data to facilitate scientific investigation. A large portion of the CDDIS holdings of GPS, GLONASS, laser ranging, VLBI, and DORIS data are stored on-line for remote access. Information about the system is available via the web at the URL http://cddis.gsfc.nasa.gov. The current and future plans for the system's support of the IVS are discussed below.

2. System Description

The CDDIS archive of VLBI data and products are accessible to the public via anonymous ftp access.

2.1. Computer Architecture

The CDDIS is operational on a dedicated UNIX server which has over 540 Gbytes of on-line magnetic disk storage (470 Gbytes in RAID storage); approximately 25 Gbytes are devoted to VLBI activities. The CDDIS is located at NASA GSFC and is accessible to users 24 hours per day, seven days per week.

2.2. Staffing

Currently, a staff consisting of one NASA civil service employee and 2.5 contractor employees supports all CDDIS activities (see Table 1 below).

3. Archive Content

The CDDIS has supported GSFC VLBI coordination and analysis activities for the past several years through an on-line archive of schedule files, experiment logs, and data bases in several formats. This archive has been expanded for the IVS archiving requirements.

The IVS data center content and structure is shown in Table 2 below (a figure illustrating the flow of information, data, and products between the various IVS components was presented in the CDDIS submission for the 2000 IVS annual report). In brief, an incoming data area has

Table 1. CDDIS Staff

Name	Position
Ms. Carey Noll	CDDIS Manager
Dr. Maurice Dube	Head, CDDIS contractor staff and senior programmer
Ms. Ruth Labelle	Request coordinator
Ms. Laurie Batchelor	Senior technical specialist (part-time)

been established on the CDDIS host computer, cddisa.gsfc.nasa.gov. Operations and analysis centers deposit data files and analyzed results using specified file names to appropriate directories within this filesystem. Automated archiving routines, developed by GSFC VLBI staff, peruse the directories and migrate any new data to the appropriate public disk area. These routines migrate the data based on the file name to the appropriate directory as described in Table 2. Index files in the main subdirectories under ftp://cddisa.gsfc.nasa.gov/pub/vlbi are updated to reflect data archived in the filesystem. Furthermore, mirroring software has been installed on the CDDIS host computer, as well as all other IVS data centers, to facilitate equalization of data and product holdings among these data centers. At this time, mirroring is performed between the IVS data centers located at the CDDIS, the Bundesamt für Kartographie und Geodäsie in Leipzig, and the Observatoire de Paris.

The public filesystem in Table 2 on the CDDIS computer, accessible via anonymous ftp, consists of a data area, which includes auxiliary files (e.g., experiment schedule information, session logs, etc.) and VLBI data (in both data base and NGS card image formats). A products disk area has also been established to house analysis products from the individual IVS analysis centers as well as the official combined IVS products. A documents disk area contains format, software, and other descriptive files.

4. Data Access

During 2004, over 100 user organizations accessed the CDDIS on a regular basis to retrieve VLBI related files. Nearly 20K VLBI-related files were downloaded per month from the archive.

5. Future Plans

The CDDIS staff will continue to work closely with the IVS Coordinating Center staff to ensure that our system is an active and successful participant in the IVS archiving effort. A new Linux server was procured in 2002; additional RAID disks and a dedicated DLT tape backup system were also purchased. The CDDIS staff plans to make this new system (cddis.gsfc.nasa.gov) operational for most data sets by the end of January 2005; implementation of the IVS support on this new server is scheduled for completion by mid-2005.

Table 2. IVS Data and Product Directory Structure

Directory	Description
Data Directories	
vlbi/ivsdata/db/*yyyy*	VLBI data base files for year *yyyy*
vlbi/ivsdata/ngs/*yyyy*	VLBI data files in NGS card image format for year *yyyy*
vlbi/ivsdata/aux/*yyyy*/*ssssss*	Auxillary files for year *yyyy* and session *ssssss*; these files include: log files, wx files, cable files, schedule files, correlator notes
Product Directories	
vlbi/ivsproducts/crf	CRF solutions
vlbi/ivsproducts/eopi	EOP-I solutions
vlbi/ivsproducts/eops	EOP-S solutions
vlbi/ivsproducts/trf	TRF solutions
vlbi/ivsproducts/trop	Troposphere solutions
Project Directories	
vlbi/ivs-iers	IVS contributions to the IERS
vlbi/ivs-pilot2000	IVS Analysis Center pilot project (2000)
vlbi/ivs-pilot2001	IVS Analysis Center pilot project (2001)
vlbi/ivs-pilotbl	IVS Analysis Center pilot project (baseline)
vlbi/ivsproducts/ivs-pilottro	IVS Analysis Center pilot project (troposphere)
Other Directories	
vlbi/ivscontrol	IVS control files (master schedule, etc.)
vlbi/ivsdocuments	IVS document files (solution descriptions, etc.)

Italy CNR Data Center Report

M. Negusini, P. Sarti, S. Montaguti

Abstract

This report summarizes the activity of the Italy CNR VLBI Data Center. We also report about some major changes that occurred during the year 2004: we have changed the affiliation of our Institute and the location of the DC, officially starting from 1st January 2005. Modification of names and codes necessary for the IVS affiliation will be requested and performed during year 2005. A new contact person for the IVS DC will be indicated.

1. Introduction

Our geodesy section and its Data Center moved to the Bologna headquarters in 2004, leaving its former location situated at the Center of Space Geodesy, Matera. This decision partly originated from the reorganization process started in June 2003 by the Italian Government, in which the Institute of Radioastronomy (IRA) was integrated into INAF (the Italian National Institute for Astrophysics; http://www.inaf.it). Therefore, starting 1st January 2005, IRA is no longer part of the National Research Council (CNR). The structure of IRA, as well as its territorial organization, has changed: it is now a section of INAF, the latter being the main institute. In its constitution act, INAF is explicitly indicated as the national institute in charge of promoting, both at national and international levels, the activities related to astronomy, astrophysics and radioastronomy. The geodetic activity of IRA has been maintained within the new institute but the geodetic division has changed location and structure. At the moment, the main analysis activity and storage is concentrated in Bologna, where we store and analyze single databases, using CALC/SOLVE software. We are using f-solve regularly updated.

The IRA has started to store VLBI geodetic databases from 1989, but the databases archived in Bologna mostly contain data including European antennas, starting from 1987. In particular most of the databases available here have VLBI data with at least three European antennas. However we have also stored all the databases with Ny-Ålesund antenna observations. Since 2002, we store all the databases available on the IVS data centers, starting from 1999. All the databases have been processed and saved with the best selection of the parameters for the final arc solutions. In order to perform global solutions, we have computed and stored the superfiles for all the databases.

In some cases we have introduced the wet delay coming from GPS into the European databases (at present only for EUROPE experiments for the years 1998 and 1999), as if it was produced by a WVR. Also these databases are available and stored with a different code from the original databases. For this we have produced a modified version of DBCAL, available to external users.

2. Computer Availability and Routing Access

The main computer is an HP 785/B2600 workstation. The internet address of this computer is boira3.ira.cnr.it and the databases are stored in different directories and on different disks as well. The complete list of directories where databases are stored is the following:

1 = /data1/mk3/data1
2 = /data1/mk3/data2

4 = /data6/dbase6
6 = /data5/dbase5
5 = /data4/dbase4
7 = /data7/dbase7
8 = /data8/dbase8
9 = /data9/dbase9
10= /geo/data
11= /geo/1999
12= /geo/2000

The username for accessing the database at the moment is geo. The password can be requested by sending an e-mail to negusini@ira.cnr.it.

The main computer that was formerly located in Matera, and that has been moved to Bologna, is an HP282 computer with internet address hp-j.ira.cnr.it. The databases are stored in the following directories:

7 = /data8/dbase8
8 = /data10/dbase10

The superfiles are stored in different directories:

/data2/super
/data10/super10
/data9/super9
/data8/super8

The list of superfiles is stored in the file /data6/solve_files/SUPCAT. The area for data storage has a capacity of up to 250 gigabytes with the installation of an external server. The data can be accessed using the username geo, and the password can be requested writing to negusini@ira.cnr.it.

Data Center at NICT

Yasuhiro Koyama

Abstract

The Data Center at National Institute of Information and Communications Technology archives and releases the databases and analysis results processed at the Correlation Center and the Analysis Center at National Institute of Information and Communications Technology. Regular VLBI sessions with the Key Stone Project VLBI Network were the primary objects of the Data Center. These regular sessions continued until the end of November 2001. In addition to the Key Stone Project VLBI sessions, National Institute of Information and Communications Technology has been conducting geodetic VLBI sessions for various purposes and these data are also archived and released by the Data Center.

1. Introduction

In April 2004, Communications Research Laboratory was integrated into the Telecommunications Advanced Organization of Japan (TAO) and the National Institute of Information and Communications Technology (NICT) was established as a new institute. The IVS Data Center at NICT archives and releases the databases and analysis results processed by the Correlation Center and Analysis Center at NICT. Major parts of the data are from the Key Stone Project (KSP) VLBI sessions [1] but other regional and international VLBI sessions conducted by NICT are also archived and released. Since routine observations of the KSP network terminated in the end of November 2001, there were no additional data for the KSP regular sessions since 2002. In 2004, three geodetic VLBI sessions were carried out and processed. The analysis results in the SINEX (Solution Independent Exchange) file format and other form of data formats are available from the WWW server. Database files generated with the Mark III database file format are available upon request and will be sent to the users in DDS tape cartridges. Database files of non-KSP sessions, i.e. other domestic and international geodetic VLBI sessions, are also available from the FTP server. Table 1 shows the list of WWW server locations maintained by the Data Center at NICT. An FTP server has also been used to provide data files, but it was decided to terminate the FTP service considering the security risk of maintaining an anonymous FTP server. Instead, the WWW server www3.nict.go.jp was prepared to hold large size data files.

Table 1. URL of the WWW server systems.

Service	URL
KSP WWW pages	`http://ksp.nict.go.jp/`
IVS WWW mirror pages	`http://ivs.nict.go.jp/mirror/`
Data server	`http://www3.nict.go.jp/dk/c256/ivs/`

The maintenance of these server machines has been moved from the VLBI research group of the NICT to the common division for the institutional network service of the laboratory in 2001 to improve the network security of these systems.

2. Data Products

2.1. KSP VLBI Sessions

The KSP VLBI sessions were performed with four KSP IVS Network Stations at Kashima, Koganei, Miura, and Tateyama on a daily or bi-daily (once every two days) basis until May 1999. The duration of each session was about 23.5 hours. Within the period, daily observations were performed from March 1 until April 1, 1999 to obtain continuous VLBI data series for various investigations such as studies about the atmospheric delay models and for the improvements of the data analysis technique. The high-speed ATM (Asynchronous Transfer Mode) network line to the Miura station became unavailable in May 1999 and the real-time VLBI observations with the Miura station became impossible. After this time, the real-time VLBI sessions were performed with three stations at Kashima, Koganei, and Tateyama. Once every six days (every third session), the observed data were recorded to the K4 data recorders at three stations and the Miura station participated in the sessions with the tape-based VLBI technique. In this case, the observed data at three stations except for the Miura station were processed in real-time and the analysis results were released promptly after the observations completed. A day later, the observed tapes were transported from Kashima, Miura, and Tateyama stations to Koganei station for tape-based correlation processing of the full six baselines. After the tape-based correlation processing completed, the data set produced with the real-time VLBI data processing was replaced by the new data set.

In July 2000, unusual site motion of the Tateyama station was detected from the KSP VLBI data series, and the frequency of the sessions was increased from bi-daily to daily since July 22, 2000. The daily sessions were continued until November 11, 2000, and the site motion of the Tateyama and Miura stations were monitored in detail. During the period, it was found that Tateyama station moved about 5 cm to the northeast direction. Miura station also moved about 3 cm to the north. The unusual site motions of these two stations gradually settled and the current site velocities seems to be almost the same as the site velocities before June 2000. By investigating the time series of the site positions, the unusual site motion started from sometime between the end of June 2000 and the beginning of July 2000. At the same time, volcanic and seismic activities near the Miyakejima and Kozushima Islands began. These activities are believed to have caused the regional crustal deformation near the area, and the unusual site motions at Tateyama and Miura are explained by the event.

2.2. Other VLBI Sessions

In addition to the KSP regular VLBI sessions, domestic and international geodetic VLBI sessions have been conducted by NICT in cooperation with Geographical Survey Institute (GSI) and other organizations. These sessions are listed in Table 2. The observed tapes of these sessions were correlated by using the K-4 correlator and the software correlation programs (K-5 correlator) at NICT either at Koganei or at Kashima.

In 2004, two e-VLBI sessions (tsev7 and tsev8) were performed for two hours and one hour, respectively, with Kashima 34m and Westford stations in cooperation with Haystack Observatory. The purpose of these experiments was to demonstrate rapid turnaround processing of the international VLBI observations by using e-VLBI. Especially, it was demonstrated that UT1-UTC can be estimated within 4.5 hours from the observations from the session tsev8 performed on June 29,

Table 2. Geodetic VLBI sessions conducted by NICT (since 2002)

Year	exp. names	sessions
2002	HOKT	HOKT02
	CUTE	CUTE01, CUTE02, CUTE03
	Usuda	USUDA1
2003	CUTE	CUTE04
	K5 Test	U03031, JD0306
	e-VLBI	evlbi4, tsev6
	Nozomi	34 sessions
	Hayabusa	10 sessions
2004	e-VLBI	tsev7, tsev8
	Geodetic	U04306
	Hayabusa	5 sessions
	Huygens	2 sessions

2004 [2]. One geodetic VLBI session, U04306, was performed to determine the precise position of the new VLBI observing site at Uchinoura. The station is a 34-m antenna station operated by the Japan Aerospace Exploration Agency (JAXA), and is located in the Uchinoura Space Center of JAXA. In the session, Kashima 34-m station and Tsukuba 32-m station were used along with the Uchinoura 34-m station. The K5/VSSP (Versatile Scientific Sampling Processor) system was used at the three stations and the data were correlated by the K5 software correlator program.

Hayabusa spacecraft was launched on May 9, 2003 by JAXA to investigate the asteroid Itokawa. The X-band telemetry signal from the spacecraft is used to demonstrate precise orbit determination by means of differential VLBI observations. Since precise orbit determination of the spacecraft Hayabusa is required to efficiently navigate the spacecraft to approach the asteroid Itokawa, many VLBI stations in Japan including the 34-m and 11-m VLBI stations at Kashima and the 11-m VLBI station at Koganei participated in the observations. The spacecraft Hayabusa is expected to arrive at the asteroid Itokawa in 2005 and precise orbit determination of the spacecraft will be essential to make the mission successful.

Huygens sessions were the preliminary rehearsal VLBI sessions conducted by many VLBI stations in USA, China, Australia, and Japan. In Japan, only the 34-m station at Kashima has the capability to receive the 2040MHz signal from the Huygens probe and participated in the rehearsal VLBI session. The probe landed on the surface of the Saturnian satellite Titan on January 14, 2005 and the 34-m station at Kashima participated in the VLBI observations.

Figure 1 shows the number of geodetic VLBI sessions and number of valid observed delays used in the data analysis for each year up to the year 2004.

3. Staff Members

The data center at NICT is operated and maintained by the Radio Astronomy Applications Group at Kashima Space Research Center, NICT. The staff members are listed in Table 3.

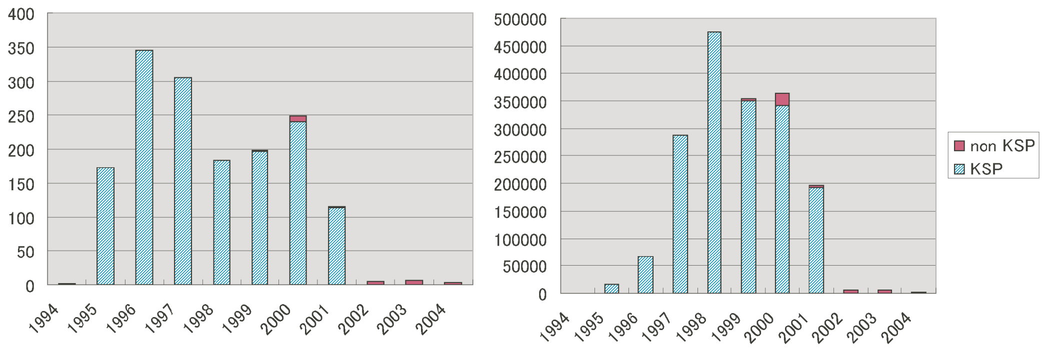


Figure 1. Number of sessions (left) and observed delays (right) used in the data analysis.

Table 3. Staff members of Radio Astronomy Applications Group, KSRC, NICT

Name	Main Responsibilities
Tetsuro KONDO	Group Leader
Eiji KAWAI	Antenna System
Yasuhiro KOYAMA	International e-VLBI
Ryuichi ICHIKAWA	Spacecraft Orbit Determination
Junichi NAKAJIMA	VLBI System Developments
Mamoru SEKIDO	Spacecraft Orbit Determination
Hiroshi TAKEUCHI	VLBI System Developments
Moritaka KIMURA	VLBI System Developments
Hiromitsu KUBOKI	Antenna System
Thomas HOBIGER	Visiting Researcher
Eric VIDAL	Visiting Researcher
Jose ISHITSUKA	Visiting Researcher

4. Future Plans

Although the regular VLBI sessions with the KSP VLBI network finished in 2001, the IVS Data Center at NICT will continue its service and will archive and release the analysis results accumulated by the Correlation Center and Analysis Center at NICT. In addition, a number of VLBI sessions are planned to be conducted for the purposes of various technology developments.

References

[1] Special issue for the Key Stone Project, J. Commun. Res. Lab., Vol. 46, No. 1, March 1999

[2] Yasuhiro Koyama, Tetsuro Kondo, Hiroshi Takeuchi, Masaki Hirabaru, David Lapsley, Kevin Dudevoir, and Alan Whitney, Rapid UT1-UTC estimation from Westford-Kashima e-VLBI experiment (2), IVS NICT TDC News, No. 24, Jul. 2004, pp. 2-6

Paris Observatory (OPAR) Data Center

Najat Essaïfi

Abstract

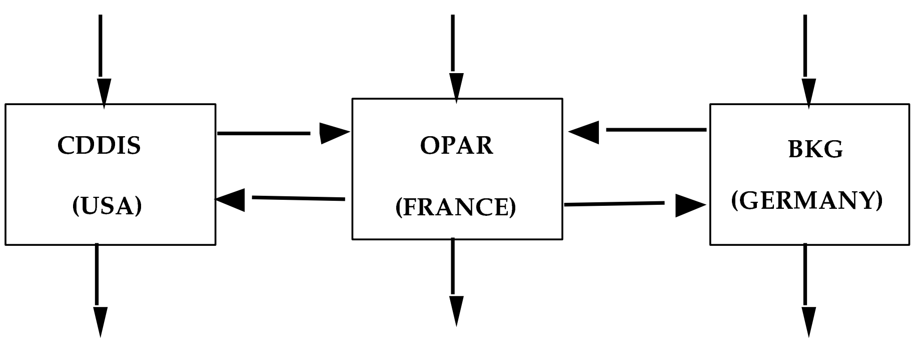
This report summarizes the OPAR Data Center activities over 2004. Included is information about functions, architecture, status, future plans and staff members of OPAR Data Center.

1. OPAR Data Center Functions

The Paris Observatory (OPAR) has provided a Data Center for the International VLBI Service for Geodesy and Astrometry (IVS) since 1999. The OPAR as well as CDDISA and BKG is one of the three IVS Primary Data Centers. Their activities are done in close collaboration for collecting files (data and analysis files), and making them available to the community as soon as they are submitted.

The three data centers have a common protocol and each of them:

- has the same directory structure (with the same control file),
- has the same script,
- is able to receive all IVS files (auxilliary, database, products, documents),
- mirrors the other ones every three hours,
- gives free FTP access to the files.



This protocol gives the IVS community a transparent access to a data center through the same directory, and a permanent access to files in case of a data center breakdown.

2. Architecture

To be able to put a file in a Data Center, operational and analysis centers have to be registered by the IVS Coordinating Center. The file names have to conform to the name conventions. A script checks the file and puts it in the right directory. The script undergoes permanent improvement and takes into account the IVS components' requests.

The structure of IVS Data Centers has evolved since 2002, the Pilot Project for baseline product has been added:

```
ivscontrol/       : provides the control files needed by the data center
                    (session code, station code, solution code...)
ivsdocuments/     : provides documents and descriptions about IVS products
ivsdata/          : provides files related to the observations:
   aux/           :   auxilliary files (schedule, log...)
   db/            :   observation files in data-base CALC format
   ngs/           :   observation files in NGS format
   sinex/         :   observation files in SINEX format
ivsproducts/      : provides results from Analysis Center:
  eopi/           :   Earth Orientation Parameters, intensive sessions
  eops/           :   Earth Orientation Parameters, sessions of 24h
  crf/            :   Celestial Reference Frame
  trf/            :   Terrestrial Reference Frame
  daily_sinex/    :   Time series solutions in SINEX format of Earth
                      orientation and site positions
  trop/           :   Tropospheric time series (starting july 2003)
ivs-iers/         : provides products for IERS Annual Report
ivs-pilot2000/    : provides products of 2000 for special investigations
ivs-pilot2001/    : provides products of 2001 for special investigations
ivs-pilottro/     : provides tropospheric time series for Pilot Project
                       (until june 2003)
ivs-pilotbl/      : provides baselines files
```

3. Current Status

The OPAR data center is operated actually on a PC located at Paris Observatory, and running the Debian Linux operating system. To make all IVS products available on-line, the disk storage capacity was significantly increased and the server is equipped now with more than 120 Gb disc storage for VLBI activities.

The OPAR server is accessible 24 hours per day, seven days per week through Internet connection with 2Mbit/s rate. Users can get the IVS products by using the FTP protocol. Access to this server is free for users.

FTP access:

ivsopar.obspm.fr
username : anonymous
password : your e-mail
cd vlbi (IVS directory)

4. Future plans

The OPAR staff will continue to work with the IVS community and in close collaboration with the two other Primary Data Centers in order to provide public access to all VLBI related data. To ensure better access to the OPAR Data Center the staff is studying some computer system enhancements, including a RAID disk system.

5. Staff Members

Staff members who are contributing to Data Center and OPAR Analysis for IVS are listed below :

- Najat Essaïfi, Data Center manager.
- Christophe Barache, Data center and data analysis.
- Anne-Marie Gontier, responsible for GLORIA analysis software.
- Martine Feissel, scientific developments.
- Daniel Gambis, interface with IERS activities.

6. Contact Information

To obtain informations about the OPAR data center please contact:

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Analysis Centers

Analysis Center of Saint-Petersburg University

Maria Kudryashova, Veniamin Vityazev

Abstract

The contribution of the Analysis Center of Saint Petersburg University for IVS in the year 2004 consists in routine estimations of EOP time series and UT1-UTC values. Information about activity, staff members and background information is included in this report.

1. Introduction

Sobolev Astronomical Institute is located in Petrodvorets, near St. Petersburg. It is a research institute of the Saint Petersburg State University. In 1998 the institute became an IVS Analysis Center at Saint Petersburg University. The main activity of AC SPU for the International VLBI Service consists of routine processing of R1, R4, and Int1 sessions (and their predecessors).

2. Activities in 2004

This year we continued to contribute our time series to IVS. Detailed description of our spu0002.eopi solution (time series which is the result of Int1 observational program processing) is given in [1]. The routine data processing requires a number of typical actions, so we focussed our efforts on the automation of this process. As a result, processing of intensive sessions is almost completely automated.

As for 24-hour sessions, during the processing of some sessions the χ^2 value may become greater than one. In this case OCCAM software automatically reweights "bad" observations. It may occur that automatic reweighting is not enough. Usually this is caused by nonlinear behavior of clocks at one VLBI site. In this case, there are few ways to correct the situation: for example, to consider clock rate of the site as a stochastic process or to correct the "jump" in maser behavior. At this stage we have some problems with complete automation of the procedures. The main details of the EOP time series spu0003i.eops preparation are summarized below:

- Data span: 1989.01.02-2004.12.29
- Estimated parameters:
  1. TRF: for stations with unstable coordinates we estimate corrections for their locations for every session. VTRF2003 is used as an a priory TRF.
  2. EOP: $x, y, UT1 - UTC, d\psi, d\varepsilon$
  3. troposphere: troposphere gradients are estimated as constant parameters, wet troposphere delay is modeled as a random walk process.
  4. station clocks are treated as follows: offset as a random walk process, rate as a constant
- nutation model: IAU 1980
- technique: Kalman filter
- software: OCCAM v.5_1

Also, during the past year work on the preparation of a global solution was conducted at the analysis center. At this stage we studied the problem of selecting stable radiosources, whose coordinates could be estimated as global parameters. First results were reported in [2].

3. Staff

The staff members who are involved in the activities of the Analisys Center are listed below:

- Veniamin Vityazev – Director of Astronomical Institute of Saint-Petersburg University, PhD., Prof. General coordination and support of activity at the Astronomical Institute.
- Maria Kudryashova – Research assistant of Astronomical Institute of Saint-Petersburg University. Processing of VLBI data.
- Julia Sokolova - Student of Saint-Petersburg University. Processing of VLBI data. Graduated from Saint-Petersburg University in Oct, 2004. Since the date, J.Sokolova is working at the Institute of Applied Astronomy.

References

[1] Kudryashova, M., Analysis center of St. Petersburg University In: International VLBI Service for Geodesy and Astrometry 2003 Annual Report, NASA/TP–2004-212254, N. R. Vandenberg and K. D. Baver (eds.), 161–162, 2003.

[2] Sokolova, J., Influence of the early VLBI observations on the ICRF stability, In: Proc. Journees 2004, Paris, 2004, under preparation.

Geoscience Australia Analysis Center

Oleg Titov, Ramesh Govind

Abstract

This report gives an overview about the activities of the Geoscience Australia IVS Analysis Center during the 2004 year.

1. General Information

The Geoscience Australia (GA) IVS Analysis Center is located in Canberra. After some organizational changes the Space Geodesy Analysis Center became a part of the Geohazard Division.

2. Component Description

Currently the GA IVS Analysis Center contributes nutation offsets, three EOPs and their rates on regular basis for IVS-R1 and IVS-R4 networks and their predecessors (IRIS-A, NEOS-A). The EOP time series from 1983 to 2004 are available. Also the CRF catalogues using a global set of VLBI data since 1980 are regularly submitted.

3. Staff

- Dr. Ramesh Govind - Director of the Space Geodesy Analysis Center
- Dr. Oleg Titov - project officer of the Space Geodesy Analysis Center

4. Current Status and Activities

The last global solution has been done using the new features of the OCCAM 6.1 software. VLBI data comprising 3177 daily sessions from 25-Nov-1979 till 21-Oct-2004 have been used to compute the global solution aus2005a. This includes 3,170,447 observational delays from 746 radiosources observed by 57 VLBI stations. Weighted root-mean-square of the solution is about 0.62 cm (about 21 picosec).

The aus2005a solution strategy used radiosources as close as possible to the ICRF-Ext.2 [1]. The radiosource catalogue included 639 sources. Coordinates of 207 of the 212 defining sources [2] were treated as global and imposed by the NNR constraints. 107 "other" sources were treated as local and their positions were estimated for each VLBI session. The rest of the 432 sources were treated as global parameters without NNR constraints.

Station coordinates were also estimated using NNR and NNT constraints. The long-term time series of the station coordinates have been established to estimate the corresponding velocities for each station. Due to a limited amount of observations the velocities have been estimated for 52 stations only. The tectonic motion of the Gilcreek VLBI site after the Denali earthquake is modelled using an exponential function [3].

The adjustment has been done by least squares collocation method, which considers the clock offsets, wet troposphere delays and troposphere gradients as stochastic parameters with apriori covariance functions. The gradient covariance functions were estimated from the GPS hourly values [4].

The relative orientation and deformation parameters to transform aus2005a to ICRF-Ext.2 were calculated using the approach by Feissel and Essaifi [5]. Table 1 shows estimates of the rotation angle between the aus2005a catalogue and ICRF-Ext.2. Solution 1 includes all sources (of the 207 imposed by NNR constraints) having more than 1 observation. Solution 2 includes sources having more than 20 observations. Both solutions demonstrate that only shift around pole (A3) and declination bias Bδ estimates are significant. Other parameters look negligible.

Table 1. Num - the number of sources; A1,A2,A3 - the rotation angles between axes of aus2005a and ICRF-Ext.2 frames; Dα, Dδ - the linear trends as function of declination; Bδ - the declination bias parameter; r(α), r(δ) - the weighted rms. All units in μas.

Solution	Num	A1	A2	A3	Dα	Dδ	Bδ	r(α)	r(δ)
Solution 1	202	-7 +/- 6	1 +/- 8	51 +/- 19	0.6 +/- 0.4	1.2 +/- 0.4	-70 +/- 20	184	190
Solution 2	194	-8 +/- 6	1 +/- 8	44 +/- 18	0.5 +/- 0.4	1.2 +/- 0.4	-68 +/- 19	174	165

Also the GA Analysis Center continues the regular submission of EOPs to the IVS/IERS and works on the development of long-term time series for the EOP, station coordinates and comparison of techniques (VLBI, SLR, GPS) for EOP and ITRF adjustment.

5. Geodetic Activity of the Australian Radiotelescopes

During 2004 two Australian radiotelescopes (Hobart and Parkes) were involved in geodetic VLBI observations. GA geodetic group promoted the observations in different ways.

In August 2004 the Hobart radiotelescope was surveyed by conventional survey techniques so as to enable the recomputation of the local tie between the radio telescope, used for VLBI, and the IGS geodetic GPS antenna located nearby. In addition to these observations, further conventional survey observations and a precision terrestrial photogrammetry survey were undertaken in an attempt to quantify the gravitational sag of the radio telescope. It was determined that, as a function of the telescope's pointing elevation and azimuth, the distance between the telescope receiver and the reference point varied by approximately 2 mm. A gravitational sag model for the Hobart telescope is developed and an assessment of its impact on geodetic VLBI is being made.

The operations of the Hobart telscope for geodetic VLBI is supported through an Australian Research Council (ARC) grant awarded jointly to the University of Tasmania (UTAS) and GA. A consortium which includes among others the UTAS and GA, was awarded an ARC grant to put optical fiber links from the Mount Pleasant VLBI site to the UTAS building: eVLBI in Hobart is getting close to being a reality.

6. Future Plans

- update OCCAM software
- combined estimation of the EOPs using VLBI, SLR and GPS data
- cooperation with the Australian National University (ANU), Australian National Telescope

Facility (ANTF) and University of Tasmania on development of VLBI for the southern hemisphere

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Bordeaux Observatory Analysis Center Report

Patrick Charlot, Antoine Bellanger, Alain Baudry

Abstract

This report summarizes the activities of the Bordeaux Observatory Analysis Center during the year 2004. On the analysis side, we have completed processing of six years of NEOS-A/IVS-R4 data (1999–2004) and two years of IVS-R1 data (2003–2004). On the research side, our major achievements include initial analysis of the three experiments conducted as part of our ICRF densification project in the northern sky, evaluation of astrometric suitability for an additional 96 ICRF sources at X band – all of which are in the southern sky – and another 122 sources at K band. Plans for the year 2005 follow the same analysis and research lines.

1. General Information

The Observatory of Bordeaux is located in Floirac, near the city of Bordeaux, in the southwest of France. It is funded by the University of Bordeaux and the CNRS (National Center for Scientific Research). During the past year, the observatory was reorganized in three scientific groups: radioastronomy, planetology, and a new group named M2A ("Métrologie de l'espace, Astrodynamique, Astrophysique"). IVS analysis and research activities (previously attached to the radioastronomy group) are now part of this new group. P. Charlot is the head of the M2A group.

The work of the Bordeaux Observatory Analysis Center is focused on the maintenance, extension, and improvement of the celestial reference frame. In particular, we lead an observing program on the European VLBI Network (EVN) to densify the International Celestial Reference Frame (ICRF) [1] and conduct research related to the effect of source structure in geodetic VLBI data [2]. Additionally, we develop routine analyses of IVS data with the aim of studying the ICRF source position stability and the physical phenomena that can affect this stability.

VLBI analyses are conducted with the MODEST software, developed and maintained by the Jet Propulsion Laboratory [3]. It is installed on a Compaq DS20 workstation along with the AIPS and DIFMAP software which are used for astrophysical imaging.

2. Scientific Staff

Our group is composed of the following three individuals, who are involved part or full time in IVS analysis and research activities, as described below:

- Patrick Charlot (50%): overall responsibility for Analysis Center work and data processing. He is the PI of the ICRF densification project on the EVN. He is also involved in radio source imaging and has a major interest in studying source structure effects in geodetic VLBI data.
- Antoine Bellanger (100%): engineer with background in statistics and computer science. His main role is to conduct initial data processing and develop analysis tools as needed. He is also currently developing a web site for the M2A group, including a section dedicated to IVS analysis activities. We expect to bring this site on-line in spring 2005.
- Alain Baudry (10%): radioastronomy expert. He is involved in the ICRF densification project and has interest in radio source imaging.

3. Analysis and Research Activities during 2004

During the past year, our level of activity has been stable. On the analysis side, we have completed initial processing of all NEOS-A and IVS-R4 sessions conducted between 1999 and 2004 along with all IVS-R1 sessions conducted in 2003 and 2004. We are now working on a so-called "arc solution" estimating monthly source positions based on this data set. In parallel, we also keep on analyzing new IVS-R1 and IVS-R4 sessions as they become available.

On the research side, a milestone was reached with the completion of initial analysis for our three EVN+ experiments dedicated to densify the ICRF in the northern sky (see [4, 5, 6] for a description of these experiments). The results show that all 150 new potential ICRF sources observed for this project have been successfully detected, hence indicating that the source selection strategy and observing scheme were appropriate [1]. About two thirds of the targets have coordinate uncertainties smaller than 1 mas (Fig. 1) and thus constitute valuable candidates for extending the ICRF. A comparison of our estimated astrometric positions with those available from the VLBA Calibrator Survey [7] for 129 common sources shows agreement within 1 mas for half of the sources and within 2 mas for 80% of the sources. EVN observing time has been approved for an additional 24-hour experiment in order to re-observe all sources with > 1 mas position errors.

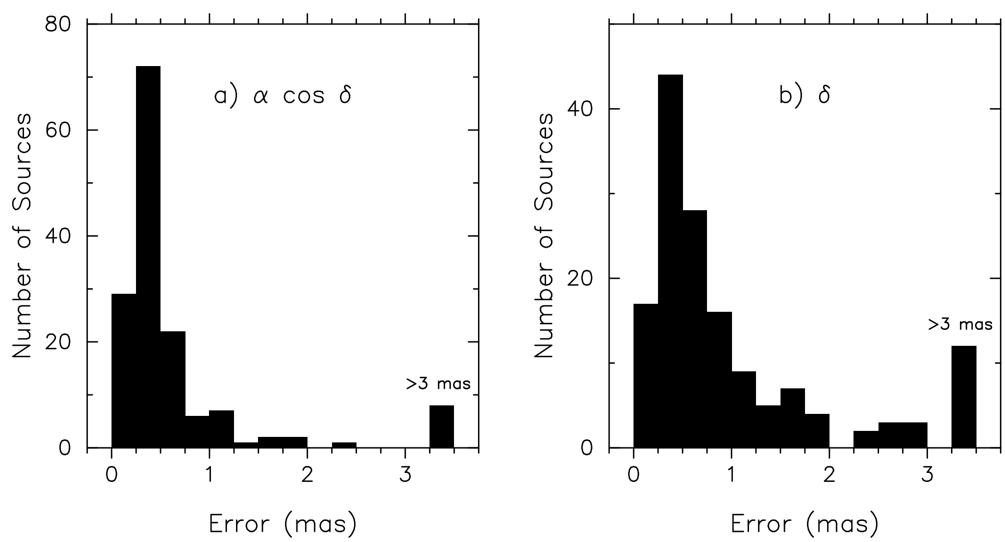

Figure 1. Error distribution in *a)* right ascension and *b)* declination for the 150 new potential ICRF sources observed in the northern sky. All errors larger than 3 mas are placed in a single bin marked with the label "> 3 mas" on each plot.

Another major achievement was the evaluation of X-band astrometric suitability for an additional 96 ICRF sources, all of which are located in the southern sky. This was made possible thanks to the southern-hemisphere imaging program initiated by the US Naval Observatory and Australia Telescope National Facility [8]. Structure indices were derived according to the average structural delay effects for these sources following our standard scheme [9]. Overall, structure indices are now available for 546 ICRF sources at X band, corresponding to 90% of the total number of ICRF sources. Analysis of the structure index distribution (Fig. 2) shows that 52% of such sources have a structure index value of either 1 or 2, indicating compact or very compact structure.

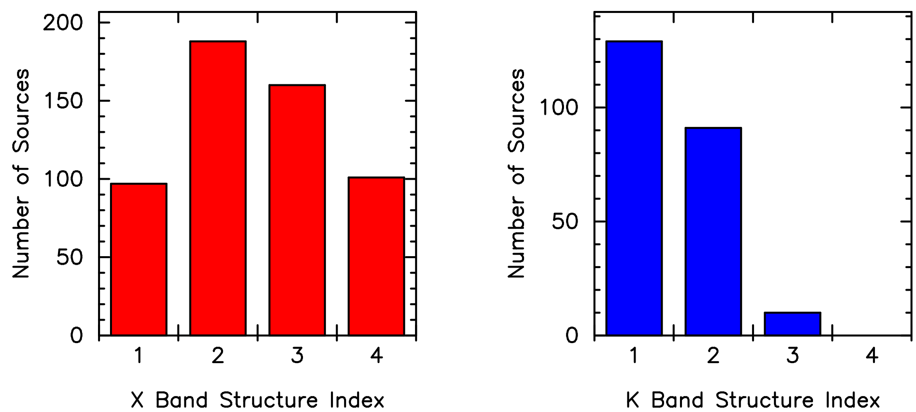

Figure 2. Current distribution of source structure indices at X band and K band. These indices are available for 546 ICRF sources at X band and 230 sources at K band. There are 167 common sources between the two samples. 54 sources observed at K band are not part of the ICRF.

Additionally, we also evaluated the astrometric suitability of another 122 sources at K band (24 GHz) based on further data acquired by the VLBA K-Q Survey collaboration [10]. Structure indices are now available for 230 sources at K band, 56% of which have a structure index value of 1 (Fig. 2). This result confirms our previous finding that the astrometric suitability of the sources is significantly better at 24 GHz than at the standard 8 GHz geodetic observing frequency [11].

4. Outlook

For the year 2005, our plans include the following:

- Keep on analyzing the new IVS-R1 and IVS-R4 sessions as they become available and set up an operational "arc position" solution to monitor the temporal evolution of the source coordinates.
- Obtain final results for the astrometric coordinates of the 150 sources observed in our ICRF densification experiments, and refine the comparison with the VLBA Calibrator Survey positions for the 129 common sources.
- Continue to evaluate the astrometric suitability of the ICRF sources as new maps become available at S, X, K and Q bands, and make the corresponding structure indices and structure correction images available through our web page.
- Assess more precisely the impact of massive source structure modeling in astrometric data analysis by repeating our previous test on the RDV data [12] after identification of the most appropriate structural reference feature for each source.
- Start processing RDV experiments in cooperation with the USNO team to monitor the X- and S-band structural evolution of the ICRF sources and extend the time basis of the current image data base.
- Finish up the design of a new web page including multi-epoch and multi-frequency structure indices and false color structure correction images, along with results of source position stability, for possible use by IVS operation and analysis centers.

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Matera CGS VLBI Analysis Center

Roberto Lanotte, Mauro Pirri, Giuseppe Bianco, Cecilia Sciarretta

Abstract

This paper reports the VLBI data analysis activities at the Space Geodesy Center (CGS) at Matera from January 2004 through December 2004 and the contributions that the CGS intends to provide for the future as an IVS Data Analysis Center.

1. General Information

The Matera VLBI station became operational at the Space Geodesy Center (CGS) of the Italian Space Agency (ASI) in May 1990. Since then it is active in the framework of the most important international programs. VLBI data analysis activities are performed at CGS for a better understanding of the tectonic motions with specific regards to the European area. The CGS, operated by Telespazio on behalf of ASI, provides full scientific and operational support using the main space geodetic techniques: VLBI, SLR and GPS.

2. Staff at CGS contributing to the IVS Analysis Center

- Dr. Giuseppe Bianco, Responsible for CGS, ASI (primary scientific/technical contact).
- Dr. Cecilia Sciarretta, Responsible for scientific activities, Telespazio.
- Dr. Roberto Lanotte, Geodynamics data analyst, Telespazio.
- Dr. Mauro Pirri, Geodynamics data analyst, Telespazio.

3. Current Status and Activities

3.1. Global VLBI Solution cgs2005a

The main VLBI data analysis activities at the CGS in the year 2004 were directed towards the realization of a global VLBI analysis, named cgs2005a, using the CALC/SOLVE software (developed at the GSFC). The cgs2005a will be included in the IVS solutions "pool" and its main characteristics are:

- Data span:
  1980.04.11 - 2004.12.31
- Estimated Parameters:
  - Celestial Frame:
    right ascension and declination as global parameters for 537 sources and as local parameters for 7 sources.
  - Terrestrial Frame:
    Coordinates and velocities for 83 stations as global parameters and as local parameters for 30 stations.

– Earth Orientation:
  Unconstrained X pole, Y pole, UT1, Xp rate, Yp rate, UT1 rate, dpsi and deps.

3.2. IVS Tropospheric Products

Regular submission of tropospheric parameters (wet and total zenith path delays, east and north horizontal gradients) for all VLBI stations observing in the IVS R1 and R4 sessions has continued during 2004.

3.3. IVS Pilot Project "Time Series of Baseline Lengths"

Regular submission of station coordinate estimates, in SINEX files, was started in 2004 for the IVS pilot project "Time Series of Baseline Lengths". At present 540 sessions have been analysed and submitted covering the period from 2000 to 2004.

3.4. Analysis of the 2004 Matera Survey and VLBI Invariant Point Determination

The role played by CGS as geodetic fundamental station, hosting the main space geodetic technique systems SLR, VLBI, and GPS, makes the whole survey theme (measurements, related corrections and processing) of great importance for the CGS activities.

The latest survey at CGS was performed in February/March 2004 and involved measurements connecting seven IERS geodetic reference points and 14 additional reference points of the local network. A technical report on the measurement procedure, with details on the local network is available at GeoDAF (Geodetic Data Archiving Facility) at the URL

http://geodaf.mt.asi.it/GDHTL/surv_rep.html.

A new software for the analysis of the survey raw measurements is under development. The main characteristics of this software are:

- atmospheric effects removed using continuously measured values of local temperature, pressure and humidity provided by the meteorological sensors operating at ASI CGS and disseminated as RINEX meteorological file in the GeoDAF database;
- rigorous network adjustment (weighted least squares method) with minimal constraints (minimal inner constraints choice is under development), using the whole covariance matrix at each step of the computation;
- outlier detection;
- designed to keep the human intervention on the data processing at the lowest;
- The VLBI invariant point can be estimated modeling the geometrical figure described by a retro-reflector located on the antenna. Using a least squares method the following three models and parameters can be estimated:
  - sphere: centre coordinates + radius
  - torus: centre coordinates + 2 radii
  - inclined torus: centre coordinates + 2 radii + 2 rotation angles

4. Future Plans

- Continue and improve the realization of global VLBI analysis.
- Continue to participate in IVS analysis projects.
- Complete the software for the analysis of geodetic local survey.

DGFI Analysis Center Annual Report 2004

Volker Tesmer, Hermann Drewes, Manuela Krügel

Abstract

This report summarizes the activities of the DGFI Analysis Center in 2004 and outlines the planned activities for the year 2005.

1. DGFI Analysis Center, General Information

The German Geodetic Research Institute (Deutsches Geodätisches Forschungsinstitut, DGFI) is an autonomous and independent research institution located in Munich. It is run by the German Geodetic Commission (Deutsche Geodätische Kommission, DGK) at the Bavarian Academy of Sciences. The research covers all fields of geodesy and includes the participation in national and international research projects as well as functions in international bodies.

The long-term research programme of DGFI is based on the general theme "Fundamentals of Geodetic Reference Systems". The definition of geodetic reference systems is studied and methods for their realisation with modern space geodetic techniques are developed. Geodetic observations are analysed, approaches for the data processing are set up, tested and exemplarily applied (see DGFI web server `http://www.dgfi.badw.de`). The major topics of its research in 2004 were:

- Geometric reference systems
- Physical reference surfaces
- Dynamic processes
- International services and projects
- Information systems and scientific transfer

DGFI contributes to the International VLBI Service (IVS) as an Analysis Center to improve the space-geodetic observation technique Very Long Baseline Interferometry (VLBI) and the analysis of its observations, respectively, by participating in pilot projects and by research projects, limited by the available personnel in operational service.

2. Activities in 2004

1. Consistent Reference Frames

   In 2004, a terrestrial reference frame (TRF), the EOP and a celestial reference frame (CRF) were estimated simultaneously in a VLBI solution (as described in e.g. Tesmer et al., 2004). The geodetic datum was realized by applying no-net-rotation (NNR) and no-net-translation (NNT) conditions for the TRF and NNR for the CRF. Such a solution is completely free of biases due to fixing reference frames (which might not be modelled consistently) or other relevant parameters of the observation equations. Due to two reasons, VLBI is especially suitable to perform such a task: Firstly, there are only several million VLBI observations which can very easily be reprocessed in a common solution although they cover more than 20 years. Secondly, the celestial VLBI reference frame consists of quasi pointlike objects (radiosources) and not of dynamic orbits which are difficult to model and valid for several days only. Hence, a major task of VLBI is to provide the link between the celestial and the terrestrial frame, including fully consistent time series of parameters to transform between the frames (pole coordinates and their first derivatives, dUT1 and LOD, as well as daily corrections to a precession-nutation model).

Until now, for 2578 sessions between 1984 and 2004, each about 24h long, normal equations were set up with the VLBI software OCCAM 6.0 (modified to allow for estimating source positions). These data include a total of 49 telescopes (of which 46 are part of ITRF2000) observing 1955 sources (of which 561 are part of ICRF-Ext1). The auxiliary parameters (for troposphere and clocks) are reduced for each session. All prereduced session-wise normal equations are then accumulated to one equation system with the DGFI software DOGS-CS and solved with an appropriate datum, namely NNR and NNT for 25 stable stations w.r.t. ITRF2000 and NNR for 199 stable sources w.r.t. ICRF-Ext1.

Besides a terrestrial (TRF) and a celestial reference frame (CRF), the solution provides time series of the EOP, referenced to the ITRF2000 and the ICRF-Ext1, as well as time series of session-wise station and source positions. Such position series should not directly be interpreted as "real" spatial movements of stations or quasars, but provide the basis for an advanced analysis of shortcomings in the modelling, such as neglected non-linear station motion or apparent motion of the quasars due to jets etc.

2. Advanced Stochastic Model for VLBI Observations

Further refinements of the functional representation of the geometric-physical properties of the VLBI observations mostly need big efforts and are not possible with any precision. Although the stochastic model is an important part of the VLBI observation equations, the stochastic properties of VLBI observations have not been studied in detail so far. The idea is to interpret discrepancies between the functional model and the observations as variances of the observations. In particular, the modelling of station and elevation dependent influences is of limited precision (in general, for present standard VLBI solutions, correlations between observations were found to be negligible).

In contrast to earlier investigations, Tesmer and Kutterer (2004) describe a solution where all of the 57 stochastic properties (station and elevation dependent portions of variance of VLBI observations), determined by means of variance covariance component estimation, were found to be stable and reliable estimates (more data was used). When applying the advanced stochastic model to parameter estimations, care has to be taken regarding indirect effects which are mainly connected with:

- the weights and the respective impact of the pseudo observations for the constraints of auxiliary clock and tropospheric parameters (to be overcome by readjusting the weights of the constraints),
- the power of outlier tests which compare observation residuals with their formal errors (to be overcome by readjusting the criterion for outlier rejection),
- the influence of observations under very low elevations, which can decisively affect the variances of the tropospheric parameters as well as their correlations with station positions, EOP and clock parameters (to be overcome by readjusting the cut off angle).

One of the major motivations for investigating the stochastic VLBI model was to improve VLBI solutions. Tests were carried out concerning the repeatability of estimated station position time series and similarity of EOP from simultaneous NEOS-A and CORE-A sessions. Both tests indicate clearly that by using the advanced stochastic model, many target parameters improve and become more realistic concerning their formal errors. But, it has to considered that further progress in the functional modelling of the VLBI observations (like, e.g., the modelling of tropospheric influences) may have a significant effect on the corresponding stochastic attributes.

3. Reliability Measures for Geodetic VLBI Products

   The reliability of geodetic VLBI products depends essentially on the checkability of the observation data and the reference frame points. First investigations to clarify the potential influence of non-detectable errors in terrestrial and celestial reference frames on VLBI products were done using the CONT02 campaign (Kutterer, 2004). This showed that proper reliability measures for VLBI products can be derived in a rigorous way using statistical test theory as background.

4. CONT02 Rigorous Combination with GPS

   The data of the IVS-initiated VLBI campaign 'CONT02' during 15 days of October 2002 are especially suitable to study the effect of combining normal equations of different space techniques on the stabilty of estimated parameters. In 2004, many investigations were carried out in close cooperation with the Research Establishment Satellite Geodesy (FESG) at the Technical University of Munich, using the CONT02 VLBI data set for advanced combination studies. A detailed description of the strategy and results are given in the paper "Combination Studies Using the CONT02 Campaign", to be found in this IVS annual report's section "Special Reports", as well as in Krügel et al. (2004).

5. IVS OCCAM Working Group

   The goal of the OCCAM working group is to constantly improve the VLBI software OCCAM. The group is chaired by Oleg Titov from Geoscience Australia (Canberra, Australia), its main members are scientists from the Vienna University of Technology (Vienna, Austria), the St. Petersburg University, the Institute of Applied Astronomy (both St. Petersburg, Russia) and DGFI. The version 6.0 of the software was officially released in February 2004 during the IVS General meeting in Ottawa, Canada (Titov et al., 2004). Since then, the software was upgraded in many parts, especially the code that solves the equation systems with the least squares approach, which now allows to also estimate source positions. This was done in very close cooperation with the Vienna University of Technology, during two small working meetings, one in March (Vienna) and one in July 2004 (Munich).

6. OCCAM VLBI SINEX files

   The IERS Combination Pilot Project, underway since the beginning of 2004, can be a major step towards more consistent, routinely generated IERS products. For this, SINEX files for each 24-hour session have to be made available by the IVS containing site coordinates and EOP (possibly quasar coordinates also). DGFI delivered accordant SINEX files to the IVS for more than 2500 sessions between 1984 and 2004, and will continue to do this for forthcoming 24-h sessions on a quasi operational basis.

3. Staff

In April 2004, Hansjörg Kutterer left DGFI to become a full professor at the geodetic institute of the University of Hannover. Manuela Krügel joined the DGFI IVS Analysis Center. The other members of the IVS Analysis Center remain Hermann Drewes and Volker Tesmer.

4. Plans for 2005

Main research goals of the DGFI IVS Analysis Center will be:

- Further improvement of the VLBI software OCCAM,
- Simultaneous and consistent determination of a TRF, a CRF and the EOP in one solution using minimum datum constraints,
- To support IVS TRF and CRF preparation activities, including submission of appropriate solutions computed at DGFI as well as analysis of solutions submitted by other analysis centers,
- To submit SINEX files for forthcoming 24-h sessions to the IVS on a quasi operational basis (as well as for older sessions if recommended),
- Combined estimation and comparative analysis of geodetic target parameters from VLBI and GPS observations.

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FFI Analysis Center

Per Helge Andersen

Abstract

FFI's contribution to the IVS as an analysis center will focus primarily on a combined analysis at the observation level of data from VLBI, GPS and SLR using the GEOSAT software. This report shortly summarises the current status of analyses performed with the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. Introduction

Recently, a number of colocated stations with more than one observation technique have been established. In principle, all instruments at a given colocated station move with the same velocity and it should be possible to determine one set of coordinates and velocities for each colocated site. In addition, a constant eccentricity vector from the reference point of the colocated station to each of the individual phase center of the colocated antennas is estimated using constraints in accordance with a priori information given by the ground surveys. One set of Earth orientation parameters (EOP) and geocenter coordinates can be estimated from all involved data types. The present dominating error source of VLBI is the water content of the atmosphere which must be estimated. The introduction of GPS data with a common VLBI and GPS parameterization of the zenith wet delay and atmospheric gradients will strengthen the solution for the atmospheric parameters. The inclusion of SLR data, which is independent of water vapour, gives new information which will help in the de-correlation of atmospheric and other solve-for parameters and lead to more accurate parameter estimates. These, and many more advantages with the combination of independent and complementary space geodetic data at the observation level, are fully accounted for the GEOSAT software developed by FFI during the last 22 years.

2. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI) and Institute of Theoretical Astrophysics, University of Oslo.

3. Combination of VLBI, GPS, and SLR Observations at the Observation Level

The GEOSAT software was recently upgraded to use numerical weather models (ECMWF) and 3D raytracing for the calculation of signal delays due to the troposphere. Ten years of VLBI data were analyzed with this feature and the improvement of the results was remarkable. A lot of experimentation must be performed before final conclusions can be drawn, but it seems that the ECMWF model needs to be scaled by one or more estimated parameters in the VLBI analyses. Plots of these estimates and spectral analyses of the results reveal interesting results. The general trend is that the ECMWF model seems to perform better at low latitudes than at higher latitudes. There is a clear seasonal signal especially for the higher latitudes. The noise level of the estimated Earth orientation parameters is typically at the level of 50 microarcseconds for the angles and

2-3 microtimeseconds for UT1. The results suggest that the applied procedure can be used to investigate how well the ECMWF model is able to describe climatic changes. Of cause, many more years of data must be analyzed for such applications.

The GEOSAT software is presently undergoing extensive development. Some of the changes are explained in our technical development report.

The BKG/GIUB VLBI Analysis Center

Volkmar Thorandt, Axel Nothnagel, Gerald Engelhardt, Markus Vennebusch, Dorothee Fischer, Dieter Ullrich, Christoph Steinforth

Abstract

The activities at the BKG/GIUB VLBI Analysis Center for the year 2004 consist of routine computations of Earth orientation parameter (EOP) time series and a number of research topics in geodetic VLBI. In 2004 the VLBI group at BKG started regular submissions of time series of tropospheric parameters for all 24 hours VLBI sessions from 1984 onward. The generation of daily SINEX (Solution INdependent EXchange format) files was continued for all available 24 hours sessions. Quarterly updated solutions were computed for the IVS products Terrestrial Reference Frame (TRF) and Celestial Reference Frame (CRF). The UT1 Intensive series was expanded by the processing of the baseline observations Tsukuba-Wettzell. At BKG also investigations related to the reliability of antenna axis offsets and radio source stability were made. At GIUB the emphasis was placed on individual research topics.

1. General Information

The BKG/GIUB VLBI Analysis Center has been established jointly by the Bundesamt für Kartographie und Geodäsie (BKG), Leipzig, and the Geodetic Institute of the University of Bonn (GIUB). Both institutions closely cooperate in the field of geodetic VLBI maintaining their own analysis groups in Leipzig and Bonn. The responsibilities include data analysis and software development. BKG is responsible for the computation of EOP time series and time series for tropospheric parameters, the generation of daily SINEX files, and quarterly updated global solutions for the TRF and the CRF. More details on the research topics of GIUB will be found below.

2. Data Analysis

At BKG the Mark 5 VLBI data analysis software system Calc/Solve, release of March 18, 2004 [1], is currently used for VLBI data processing. In addition, the older Mark IV version, release of May 15, 2003 and an independent technological software environment for the Calc/Solve software are available. The latter is used for linking up the Data Center management with the pre- and post-interactive part of the EOP series production and to monitor all Analysis and Data Center activities (Data Center topics are described in the BKG Data Center report in this issue). The Mark 4 Calc/Solve software under Fortran 77 is installed on an HP9000/280/1 workstation with an HP-UX10.20 operating system and the Mark 5 software under Fortran 90 on another HP workstation with an HP-UX11.00 operating system.

- **Processing of correlator output**
  The BKG group continued the generation of calibrated databases for the sessions correlated at the MPIfR/BKG Mark 5 Astro/Geo Correlator at Bonn (e.g. R1, T2, OHIG, EURO) and submitted them to the IVS Data Centers.
- **IVS EOP time series**
  The currently generated EOP time series bkg00006 was extracted from a global solution with 24 hour VLBI sessions since 1984. Altogether 3062 sessions were processed. The main

parameter types in this solution are globally estimated station coordinates and velocities together with radio source positions. Minimal constraints for the datum definition are applied to get zero net rotation and net translation for 26 selected station positions and velocities with respect to the VTRF2003 [2] and zero net rotation for 212 defining sources with respect to ICRF-Ext.1 [3]. The station coordinates of the stations TIGOCONC (Chile) and SVETLOE (Russia) are estimated as local parameters in each session.

The UT1 time series bkgint03 from intensive observation sessions of the baseline KOKEE-WETTZELL was expanded with observations of the baseline TSUKUBA-WETTZELL each with a duration of about 1-hour. Series bkgint03 is generated with fixed TRF (VTRF2003) and fixed CRF derived from the global BKG solution for EOP determination. The estimated parameter types are only UT1, station clock, and zenith troposphere. Currently altogether 1395 UT1 intensive sessions were analysed for the period between 1999.01.01 and 2005.01.04.

- **Quarterly updated solutions for submission to IVS**
  For the IVS products TRF and CRF quarterly updated solutions were computed. There are no differences in the solution strategy compared to the continuously computed EOP time series bkg00006. The results of the radio source positions were submitted to IVS in IERS format. The TRF solution is available in SINEX format, version 2.1, with station coordinates, velocities, and covariance matrix.

- **Tropospheric parameters**
  The VLBI group of BKG started regular submissions of long time series of tropospheric parameters to the IVS (wet and total zenith delays, horizontal gradients) for all VLBI sessions since 1984. The tropospheric parameters are directly extracted and transformed into SINEX for tropospheric estimates from the results of the standard global solution for the EOP time series bkg00006.

- **Daily SINEX files**
  The VLBI group of BKG continued the regular submissions of daily SINEX files for all available 24 hours sessions as base solutions for the IVS time series of baseline lengths and for combination techniques. In addition to the global solutions independent session solutions were computed for the parameter types station coordinates, EOP, and nutation parameters.

3. Research Topics

- **Reliability of antenna axis offsets**
  The local measurement results from an internal BKG paper of 1996 for the VLBI antenna at OHIGGINS (Antarctic) were checked. The used value of the antenna axis offset of 0 mm was confirmed. Furthermore some test solutions with estimation of antenna axis offsets were made for the comparison with the used a priori values and as contribution for the official list of VLBI antenna axis offsets issued by the IVS Analysis Coordinator.

- **Radio source stability**
  Test basis for the analysis of unstable radio sources was the paper by Martine Feissel-Vernier [4]. 162 unstable radio source positions were estimated as global parameters with their apparent proper motions together with the no-net-rotation condition of sources w.r.t. ICRF-Ext.1 for 81 stable defining sources marked in the ICRF-Ext.1 catalogue. The results prove

that about 41 percent of the investigated sources show significant source proper motion with an amount of more than a triple standard deviation of proper motion.

- **Analysis of Tsukuba - Wettzell INT2 Series**
  The analysis of the Wettzell - Tsukuba K4 Intensive series (INT2) has been continued. This year, investigations concentrated on the effects of errors in polar motion and in the nutation offsets on the UT1-UTC estimates.

- **The Use of Water Vapour Radiometer (WVR) Data in EUROPE Sessions**
  Since early 2004 the Max-Planck-Institute for Radio Astronomy in Bonn, Germany, operates a new water vapour radiometer at Effelsberg. This radiometer has been used in the Europe-74 session in December 2004 and its use and its implications for the VLBI data analysis are being studied. For a further study WVR data is being collected from Wettzell, Onsala and DSS65.

- **Pathlength Variations at Effelsberg**
  The homologous deformation of the Effelsberg telescope most certainly also affects the signal path length prior to the horn. Investigations were started on how to measure the variations in the path length due to the deformation of the paraboloid and the position of the subreflector.

- **Combination**
  Within the GIUB group, combination software is being developed for EOP results and for TRF/EOP normal equations. These activities, as well as research in the area of VLBI antenna axis offsets and their implication for the VLBI TRF, are described in the report of the IVS Analysis Coordinator (this volume).

4. Personnel

Table 1. Personnel at BKG/GIUB Analysis Center

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[1] GSFC, NASA (2004): Release of Mark-5 VLBI Analysis Software Calc/Solve from March 18, 2004 (web-reference: http://gemini.gsfc.nasa.gov/solve).

[2] VTRF2003: A Conventional VLBI Reference Frame, Jun. 30, 2003 (web-reference: http://giub.geod.uni-bonn.de/vlbi/IVS-AC/vtrf2003/vtrf2003.html).

[3] ICRF-Ext.1 (http://hpiers.obspm.fr/webiers/results/Icrf)

[4] Feissel-Vernier M. (2003): Selecting stable extragalactic compact radio sources from the permanent astrogeodetic VLBI program, In: Astronomy and Astrophysics, 403, 105-110, 2003.

GSFC VLBI Analysis Center

David Gordon, Chopo Ma, Dan MacMillan, Leonid Petrov, Karen Baver

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2004. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development activities aimed at improving the VLBI technique.

1. Introduction

The GSFC VLBI Analysis Center is located at NASA's Goddard Space Flight Center in Greenbelt, Maryland. It is part of a larger VLBI group which also includes the IVS Coordinating Center, the Core Operation Center, a Technology Development Center, and a network station. The analysis center participates in all phases of geodetic and astrometric VLBI analysis, software development, and research aimed at improving the VLBI technique.

2. Activities

2.1. Analysis Activities

The GSFC analysis group routinely analyzes all Mark IV/5 IVS sessions using the Calc/Solve system, and performs the AIPS fringe fitting and Calc/Solve analysis of the VLBA-correlated RDV sessions. It submits updated EOP files and daily Sinex solution files for all IVS sessions to the IVS Data Centers immediately after analysis. The group also submits the analyzed databases to IVS for all INT01 NEOS Intensive, R1, RDV, R&D, and APSG sessions. During 2004, the group processed and analyzed 152 24-hr (54 R1, 51 R4, 6 RDV, 3 R&D, 11 T2, 16 CRF, 6 OHIG, 4 EURO, and 1 APSG) sessions and 257 1-hr UT1 (212 INT01, and 45 INT02) sessions. The group also generated and submitted 3 quarterly updated TRF solutions to the IVS Data Centers using all suitable VLBI sessions.

2.2. Research Activities

The GSFC analysis group performs research aimed at improving the VLBI technique. The primary research activities undertaken during 2004 include the following:

- Gilcreek post-seismic behavior: Since the Denali fault earthquake in November 2002, Gilcreek's horizontal motion has shown roughly exponential transient behavior. Exponential time constants computed after about 2 years are 0.82 years and 0.62 years for eastward and northward displacement respectively. The horizontal rates have nearly returned to their long-term values prior to the earthquake but still differ by about 1.5 mm/year in both the east and north directions. Such a model was applied in the group's standard terrestrial reference frame solutions. Comparison of polar motion from the R1 sessions with the IGS series shows that the WRMS agreement is not significantly different before and after the earthquake, indicating that the model is performing reasonably well.

- Ny-Ålesund displacements and gravity: Ny-Ålesund vertical rates from VLBI and GPS, and gravimetry measurements were studied and compared. VLBI and GPS vertical rates and the rate of gravity change do not agree well with model rates that account for post-glacial rebound, present day ice melting, and relative sea-level change. A possible explanation is that the observed rate of change of gravity is in error (too large by about 50%) due to a sparsity of data (4 measurements over 5 years). Another possible explanation is that the rate of present day ice melting is significantly greater (by perhaps 50-70%) than what was nominally used in the model. The analysis models and observations are discussed in a paper submitted to Geophysical Journal International ("A Geophysical Interpretation of the Secular Displacement and Gravity Rates Observed at Ny-Ålesund, Svalbard in the Arctic", by T. Sato, J. Okuno, J. Hinderer, D. MacMillan, H. -P. Plag, O. Francis, R. Falk, Y. Fukuda).
- Reference frame scale rate: Comparison of rates from 25 co-located GPS and VLBI antennas shows that, on average, GPS vertical rates (from the JPL solution) are about 1.5 mm/yr greater than VLBI rates. Further analysis indicates a rate difference between the VLBI and GPS reference frame scales of 0.2-0.25 ppb/yr, which corresponds to the observed vertical rate difference. Both the VLBI and GPS solutions were aligned to ITRF2000, with the GPS solution also aligned in scale as well as rotation and translation. A likely source of this discrepancy is GPS error due to uncorrected orbit errors. Any scale rate difference is obviously important for resolving such effects as global sea level rise, which has been estimated to be 1-2 mm/yr. This work was presented at the Fall 2004 AGU meeting.
- Source monitoring program: Most geodetic schedules are made using sources from a catalog of ~100 sources considered the best "geodetic" sources, often with a few "non-geodetic" sources added from other lists. It was found that many of the non-geodetic sources were being observed too infrequently. Beginning in February 2004, a program was begun to systematically monitor 307 of these non-geodetic sources. This list includes all ICRF defining sources plus all sources identified by Martine Fiessel as potentially stable sources not already in the geodetic catalog. A goal of observing each of these at least twice per year was set. A database was developed to keep track of when a source was scheduled and the number of successful observations. It is updated twice for each session – before the session using the schedule, and after the session using the analyzed results. Only the R1's and RDV's are being used in this source monitoring program. This effort has been very successful. Before starting this program, ~160 of the sources had not been successfully observed during the preceding year, and only 70 had been successfully observed twice. By December 2004, only 5 had not been observed during the preceeding year, and over 250 had been observed twice.
- VCS3: A third set of VLBA calibrator sessions were observed and processed by GSFC and NRAO personnel in order to fill holes in the current geodetic/astrometric catalog. In three VCS3 sessions, positions were obtained for 360 new sources. The geodetic/astrometric catalog now contains 2262 sources with positions known to better than 5 mas. With the VCS3 data, there is now a suitable phase calibrator within 4 degrees of any point over 95% of the sky north of -45 degrees declination. A paper describing this work was submitted to the Astronomical Journal ("The Third VLBA Calibrator Survey", by L. Petrov, Y.Y. Kovalev, E. Fomalont, and D. Gordon). The full geodetic/astrometric catalog is available at http://gemini.gsfc.nasa.gov/vcs/, http://magnolia.nrao.edu/vlba_calib/index.html, or http://www.vlba.nrao.edu/astro/calib/index.html (search tool).

- Antenna thermal deformation: A simple model of antenna thermal expansion based on antenna dimensions, expansion coefficients, and measured site temperature was tested in standard VLBI analysis. Baseline length variance was reduced for nearly all baselines by as much as 20 mm^2 and on average by 8 mm^2. This improvement corresponds to 1-3 mm in station vertical precision. This model will be added to the Solve analysis program.

- Hydrology loading: The effect of hydrology loading on VLBI site position estimates was investigated. Application of model site displacements derived from the hydrology model of Milly et al. (J. Hydrometeorology, **3**, 283-299, 2002) improved baseline length repeatabilities for more than 80% of baselines and accounts for 1-5 mm in station vertical variation depending on the site.

- UT1 Intensives comparisons: A study was performed on 275 IVS-INT01 sessions (Kokee-Wettzell) and 48 IVS-INT02 sessions (Tsukuba-Wettzell) between July 2002 and December 2003. Analysis of the differences between each UT1 estimate and UT1 linearly extrapolated from the nearest 24 hour session showed that the precision of each series was 18-22 μsec. The average UT1 formal errors and session fits for the INT02 sessions (9.5 μsec and 27 μsec) were better than for the INT01 sessions (13.9 μsec and 36 μsec).

- Ter-diurnal variations: Direct estimation of harmonic EOP was performed. Several unexpected phenomena were found. There is a strong prograde narrow-band signal in polar motion around $K_1 + 2K_1^-$. There is also a narrow-band signal in UT1 at S_3 and a rather broad peak around $K_1 + 2K_1^-$ frequency. Estimates of the power spectrum around K_2 and S_2 show the presence of signal *near* these spectral lines.

- Love numbers estimation: Estimation of Love numbers from VLBI observations and their comparison with superconducting gravimetry data analysis results was performed. It was found that for diurnal and semi-diurnal bands, VLBI gives upper limit errors that are less by a factor of 2–4 than superconducting gravimetry measurements of the Earth's non-rigidity. The estimates of Love numbers at semi-diurnal bands from VLBI allows one to discriminate between theories of solid Earth tides. Also, the combination of results from VLBI and superconducting gravimetry allows estimation of the k Love number with an upper error limit for diurnal and semi-diurnal bands in the range 0.5–1.0%.

- Higher frequency CRF: Members of the analysis group are working with JPL, USNO, NRAO, and others, to extend the celestial reference frame to higher frequencies by using the VLBA at K and Q bands ($\sim$24 and $\sim$43 GHz). The primary goal is to build up a reference frame for use in planetary spacecraft navigation at Ka band ($\sim$33 GHz). A nearly simultaneous K/X/S VLBA session was observed and analyzed. The K/X, K/S, and X/S ionospheres were computed and compared. The K band ionosphere corrections showed a maximun range of $\sim$400 psec peak-to-peak at the longest baselines. At Ka band, about half as much should be seen; therefore the ionosphere delay at Ka band will need to be measured in some manner.

- Altimeter radiometer monitoring: VLBI and GPS wet zenith delay estimates were used to monitor and calibrate drifts in the sea surface radiometer measurements from the TOPEX and Jason-1 satellites. For the period 1993-1999, the VLBI drift calibration of TOPEX agrees very well with the GPS drift calibration, although it is five times noisier because there is much less VLBI intercomparison data. Also, two systematic jumps of 5 mm and 11 mm in the time series of Jason-1 radiometer measurements were identified using GPS and VLBI measurements. A paper describing this work was published in a special issue of Marine Geodesy on Jason-1 calibration.

2.3. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Updates were released approximately bimonthly during 2004.

Calc/Solve development work was concentrated on the development of a Linux and HP-UX compatible version. At year's end, most of the programs were ready. This includes the catalog system and database handler, SOLVE, the new REPA plotting program, and Calc 9.13. Completion and release is expected early in 2005.

Work was also concentrated on upgrading Calc for compliance with the IERS Conventions (2003). The Fortran 77 version was essentially completed during the past year. A Fortran 90 HP-UX/Linux version will be produced early in 2005.

Efforts were begun to develop an integrated analysis system with the program GEODYN at its base, and with capabilities to integrate VLBI, SLR, GPS, DORIS, and laser altimetry measurements at the level of the observables. Initial, limited capabilities of analyzing VLBI observations were added. This work will be carried over into 2005 and 2006.

3. Staff

Members of the analysis group and their areas of activity include: Dr. Chopo Ma (CRF, TRF, EOP, K/Q CRF, IVS representative to the IERS, and newly elected chairman of the IERS directing board), Dr. Dan MacMillan (CRF, TRF, EOP, mass loading, antenna deformation, proper motion, and post-seismic studies), Dr. David Gordon (database analysis, RDV processing and analysis, K/Q CRF analysis, VLBA calibrator surveys, Calc development), Dr. Leonid Petrov (CRF, TRF, EOP, mass loading analysis, VLBA calibrator surveys, Calc/Solve development, Linux migration, GEODYN development), Ms. Karen Baver (R4 and Intensives analysis, software development, Linux migration), and Jim Ryan (retired) (Calc/Solve Linux migration).

4. Future Plans

Plans for the next year include: Finish and release the first Linux/HP-UX version of Calc/Solve; finish the update of Calc for compliance with the IERS Conventions (2003); participate in development of the next VLBI ICRF; participate in a fourth set of VLBA calibrator survey sessions; participate in additional K/Q observations and reference frame development; continue development of GEODYN for integrated analysis of VLBI, SLR, GPS, DORIS, and laser altimetry observables; and further research aimed at improving the VLBI technique.

5. Publications

MacMillan, D. S., B. D. Beckley, and P. Fang, "Monitoring the TOPEX and Jason-1 Microwave Radiometers with GPS and VLBI Wet Zenith Path Delays", Marine Geodesy, **27**, 703-716, 2004.

MIT Haystack Observatory Analysis Center

Arthur Niell

Abstract

The primary contribution of Haystack Observatory to analysis of geodetic VLBI data is improvement of accuracy in the estimation of atmospheric delay. In the past year investigation was begun of the possible contribution of high horizontal resolution Numerical Weather Models to better understand the delay due to small-scale structure of water vapor.

1. Geodetic Research at the Haystack Observatory

The MIT Haystack Observatory is located approximately 50 km northwest of Boston, Massachusetts. Geodetic analysis activities have been primarily directed to improving the accuracy of the estimation of atmosphere delay and thus reducing errors in the geodetic analysis. This work, along with operating the geodetic VLBI correlator and with supporting operations at the Westford, GGAO, Gilmore Creek, and Kokee Park geodetic sites, is supported by NASA through a contract with the Goddard Space Flight Center.

2. High Resolution Numerical Weather Model for Atmosphere Anisotropy

New atmosphere mapping functions have previously been developed that are based on Numerical Weather Models (NWM) which provide *in situ* values for the atmosphere state variables of temperature, humidity, and pressure. These more accurate mapping functions will improve the estimation of atmosphere delay and geodetic parameters as well as allow evaluation of the errors in previous generations of mapping functions.

The two mapping functions developed for operational use, IMF [1] and VMF [2], use data from a global NWM, either the National Center for Environmental Prediction (NCEP) or the European Centre for Medium-range Weather Forecasts (ECMWF), having horizontal resolutions of 2.5° an 0.3°, respectively. Even the resolution of ECMWF, corresponding to about 30 km, is ten times larger than the scale height of the water vapor, thus significantly limiting knowledge of the horizontal variation of the delay due to water vapor. To evaluate the potential improvement in geodetic analysis through better knowledge of the anisotropy of the water vapor, I am working with Mark Leidner of Atmosphere and Environmental Research, Inc, to use weather forecasts with resolution as small as three kilometers to determine the small-scale structure of the water vapor.

To obtain this resolution the Penn State/NCAR MM5 numerical weather model software has been installed on a Linux cluster at Haystack to produce twelve hour forecasts in nested grids of 81, 27, 9, and 3 km for the stations and time period of CONT02. Eventually, three dimensional raytraces through the forecast fields will be used to provide mapping functions for the VLBI analysis of the CONT02 data.

The initial effort has been to evaluate the information obtained from the NWM by comparison with mapping functions calculated from the radiosondes profiles of temperature and humidity at sites within the three kilometer grids. We have found that, at least for the region around Westford, the calculation of the azimuthally symmetric mapping functions does not depend on the horizontal resolution or forecast time (out to twelve hours). While this is the expected result, it is necessary to validate that the MM5 is being operated at the level of accuracy needed for the VLBI analysis.

The hydrostatic mapping function comparison for the radiosonde site at Albany, NY, USA, is shown in Figure 1. The largest deviations are for radiosonde profiles that are missing significant amounts of data, suggesting that the NWM may provide a more uniform source of data, provided the accuracy is sufficient.

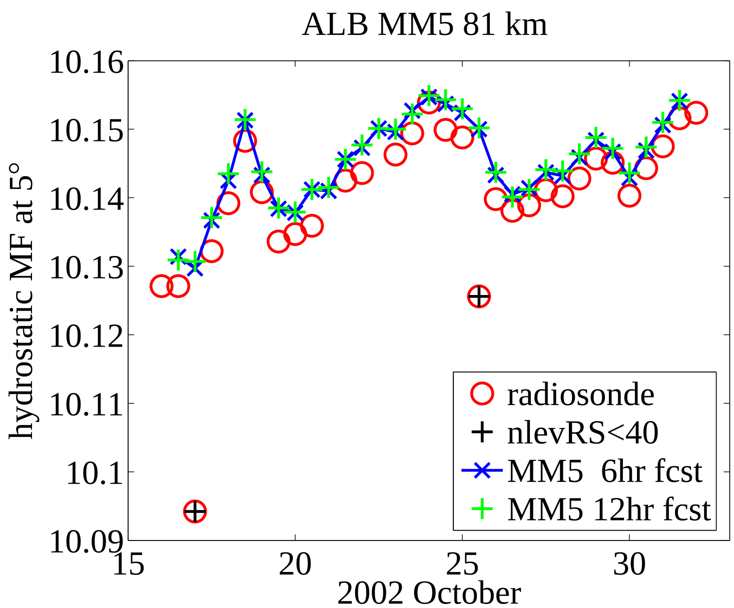

Figure 1. Hydrostatic mapping function at 5° for site ALB (Albany, NY, USA) for the CONT02 period using radiosonde data and meteorological parameters from the MM5 six and twelve hour forecasts.

3. Outlook

Following completion of validation of the vertical profiles for the other seven sites, the effects of horizontal anisotropy will be investigated. A site of particular interest is Kokee, which is in the midst of a very asymmetric water vapor field and which often must be used with a pattern of observing that is very asymmetric in azimuth.

The goal is to ascertain whether inclusion of high resolution information on the water vapor field obtained from a NWM improves the estimation of geodetic parameters for VLBI, and thus potentially for GPS.

References

[1] Niell, A.E.: Improved atmospheric mapping functions for VLBI and GPS, Earth, Planets, and Space, 52, 699-702, 2000.

[2] Boehm, J. and H.Schuh: Vienna Mapping Functions in VLBI Analyses, Geophys. Res. Letters, 2004.

IAA VLBI Analysis Center Report 2004

Zinovy Malkin, Elena Skurikhina, Alexey Melnikov, Vadim Gubanov, Sergey Kurdubov, Igor Surkis, George Krasinsky, Julia Sokolova, Nadia Shuygina

Abstract

The report contains a brief overview of IAA VLBI analysis activities in 2004 and the plans for the coming year.

1. General Information

The IAA IVS Analysis Center (IAA AC) is located at the Institute of Applied Astronomy of the Russian Academy of Sciences in St. Petersburg, Russia. Several groups are involved in VLBI data analysis and related studies. Their activities in 2004 are described below. The IAA AC web page `http://www.ipa.nw.ru/PAGE/DEPFUND/GEO/ac_vlbi/` is supported.

2. Organization and Staff

After reorganization in the end of 2004, IAA groups contributing to the IAA AC activities are:

1. Lab of Space Geodesy and Earth Rotation (LSGER): Dr. Zinovy Malkin (Head, 30%), Prof. Vadim Gubanov, Dr. Elena Skurikhina, Sergey Kurdubov, Julia Sokolova (all 100%). The main tasks of this group are EOP service, computation and investigation of operational and long-term series of EOP, station and radio source coordinates, tropospheric parameters, comparison and combination of space geodesy products. The group makes use of OCCAM/GROSS software for regular data processing. Vadim Gubanov and Sergey Kurdubov of former QUASAR Group continued development of the QUASAR software which is intended to provide complete processing of VLBI observations, global analysis in the first place.

2. Lab of Ephemeris Astronomy (LEA): Prof. George Krasinsky (Head, 80%), Nadia Shuygina (5%). The main activities of this group in VLBI analysis are using VLBI data for developing of a new Earth precession-nutation numerical model, and combining of the VLBI and satellite data for computation of daily UT1 and celestial pole offset series, and high-frequency EOP variations. This group uses a method of combination of observations obtained with different techniques at the observational level using ERA software.

Besides, Igor Surkis, now the Head of the Lab of Correlator Processing continues to help in support of QUASAR software, and Alexey Melnikov of this Lab is working on porting SKED to Linux in cooperation with the GSFC team.

3. Analysis Activities

3.1. LSGER Group

The activities of the LSGER group in 2004 were as follows:

- Development of the OCCAM/GROSS software. Main improvements made in 2004 are implementation of a Vienna Mapping Function (data provided by IGG TUW is used), output of hourly tropospheric parameters in the IVS TROPO format, adding possibility of use of non-linear station motion. Some other changes with no significant influence on the results were made.

- Operational processing of the "24h" and intensive VLBI sessions, submitting the results to the IERS and IVS. Processing of the intensive sessions is fully automated. At the moment, the EOPS series contains 2933 estimates of pole coordinates, UT1 and celestial pole offsets, and the EOPI series contains 4697 estimates of UT1.
- A new 25-year session station coordinates, baseline lengths, and tropospheric parameters (ZTD, gradients) time series were obtained. Analysis of the results is in progress.
- Session SINEX files were regularly sent to the IVS for the IVS Baseline Length PP.
- Regular computation of FCN contribution using the model proposed in [5] started in 2004, and is available at the IAA AC web page, along with regularly updated mean pole series used for modelling of the pole tide.
- Operational computation of NGS cards as requested by the IVS CC was started. All historical databases had been also processed.
- Support of IAA archive of VLBI observations and products. At present all available X and S databases and NGS cards are stored.
- Porting SKED to Linux in cooperation with GSFC was carried out, and is expected to be finished early 2005.

In 2004 the QUASAR group continued preparation for a global analysis of all available VLBI observations. Details of this project and first results can be found in [1, 2]. 1979-2002 VLBI data were processed by means of the least-squares collocation technique (LSC). Autocovariance functions (ACF) of intraday stochastic signals (UT1, WTD and clocks) were revised by using the LSC interpolation of the preliminary signals. The results show that the normalized ACF have a global nature and do not depend on site and time of observations. However, the variances of local signals vary from site to site and for different seasons (Table 1). All these data were included into the global collocation process.

Table 1. Examples of averaged WTD variances (in mm^2) for four seasons.

Station	Months				Mean	Number of sessions
	12-02	03-05	06-08	09-11		
GILCREEK	44.0	40.9	75.4	51.9	54.4	1760
KOKEE	88.2	64.8	107.4	105.2	90.8	832
WETTZELL	69.6	67.6	117.5	88.0	86.0	1773
WESTFORD	345.8	340.7	466.1	427.3	394.9	1446
NYALES20	26.5	28.0	40.7	34.4	32.4	431

Coefficients of Chebychev's expansion of EOP trends were estimated as global parameters. The regularized random EOP corrections are obtained for all series [2].

The global solution was derived from NEOS-A, NEOS-B and IVS-R4 programs. Corrections to coordinates and proper motions of 22 stations and 319 sources were calculated. Corrections to EOP were obtained as well, their uncertainties are showed in Table 2.

Table 2. WRMS of EOP uncertainties.

EOP	$\Delta\psi\cos(\epsilon)$	$\Delta\epsilon$	Δ(UT1-UTC)	ΔX_p	ΔY_p
Unit	mas	mas	0.1 ms	mas	mas
WRMS	0.074	0.109	0.067	0.107	0.118

Annual variations of the Wettzell coordinates were detected, the spectra are shown in Figure 1.

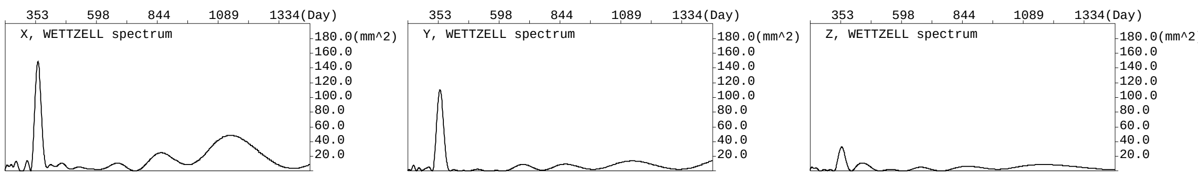

Figure 1. Power spectrum density of Wettzell coordinates variations.

The IERS Conventions (2003) algorithm of transformation between TRS and CRS was implemented.

A new procedure of source coordinates and proper motions determination is under development. Corrections are divided into systematic and random parts. Systematic components are represented as expansion by spherical functions. Its coefficients are estimated as global parameters, and random components are estimated separately in the second iteration.

The project is carried out under financial support of the Russian Foundation for Basic Research (grant No. 03-02-17591).

3.2. LEA Group

1. A preliminary version of numerical theory of rotation of the non-rigid Earth with the two-layer core is constructed and fitted to the VLBI based positions of the Celestial Pole (GSFC data of 1984-2004, 3432 points). Unlike the adopted Nutation IAU 2000, the theory describes both the nutational and precessional motions. In this preliminary analysis, effects of the inner core are considered only approximately.

From the fitting to the VLBI data the following parameters were estimated: initial values of $\theta^{(0)}$, $\phi^{(0)}$ of the Euler angles of nutation and precession referred to the ecliptical inertial frame J2000 for the initial epoch 1983 Dec 24; initial values of the derivatives $\dot{\theta}^{(0)}$, $\dot{\phi}^{(0)}$; initial values of the equatorial projections $v_1^{(0)}$, $v_2^{(0)}$ of the differential angular velocity of the core at the same epoch and reference frame; the ellipticity e of the Earth as a whole and that e_c of the core; the static k_2 and dynamic Love number k_2^d; the lags δ, δ_c of the body tide in the Earth as a whole and in the core; a parameter characterizing ocean tides; the unmodelled secular trend in the obliquity; two empirical parameters supposedly absorbing effects of the inner core. The overall post-fit RMS of the residuals $d\theta$ and $\sin\theta d\phi$ of the theory with the VLBI data under consideration is 0.20 mas.

The unmodelled obliquity rate is estimated as 1.5 ± 0.1 mas/cy being considerably less then the unmodelled rate -25 mas/cy for Nutation IAU 2000. After removing remaining annual oscillations the RMS diminishes to the values 0.169 mas for $d\theta$ and 0.190 mas for $\sin\theta d\phi$. These values are to be compared with the corresponding values 0.182 mas and 0.193 mas for Nutation IAU 2000.

The theory accounts for the relativistic geodetic precession (1980 mas/cy). Unfortunately, due to strong correlations with e and $\phi^{(0)}$, it appears that the geodetic precession cannot be estimated simultaneously with other parameters as an unmodelled secular trend in the precessional angle ϕ. Omission of this effect increases the RMS by 18 percent. Probably that is the first experimental confirmation of the effect of the geodetic precession. A preliminary version of the model is described in [3] with a short exposition given in [4].

2. Monthly series of VLBI observations obtained in the NEOS campaign and laser ranges to geodetic satellites Lageos, Lageos-2, and Etalon-1, Etalon-2 were processed applying Kalman filtering for EOP. The method used allowed us to obtain UT1 and celestial pole offset with diurnal resolution.

4. Outlook

Plans for the coming year include:

- Further improvement of algorithms and software for processing of VLBI observations.
- Continue regular computation of operational and long-time EOP, station coordinates, and troposphere parameters series with OCCAM software. Submit the results to IVS and IERS.
- Obtain first results of global analysis of the VLBI data with QUASAR software.
- Continue investigations of VLBI estimation of EOP, station coordinates, and troposphere parameters, and comparison with satellite techniques.
- Develop a model for seasonal variations of WZD [6]. Implement modelled values as a priori during data analysis.
- Resume activity in computation, investigation, combination of source catalogs. Participate in the Radio Source Catalogs IVS PP.

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Italy CNR Analysis Center Report

M. Negusini, P. Sarti, S. Montaguti

Abstract

This report summarizes the activity of the Italy CNR VLBI Analysis Center. We also report about some major changes that occurred during 2004. The institute changed its affiliation and location (officially taking effect on 1st January 2005). Modification of names and codes necessary for the IVS affiliation will be requested and performed during 2005. A new contact person for the IVS AC will be indicated. The structure and the activities of the Analysis Center remain unchanged.

1. General Information

Our geodesy section and its Analysis Center moved to the Bologna headquarter during 2004, leaving its former location situated at the Center of Space Geodesy, Matera. This decision partly originated in the reorganization process that was started by the Italian Government in June 2003 and in which the Institute of Radioastronomy (IRA) was integrated into INAF (Italian National Institute for Astrophysics; http://www.inaf.it). Therefore, starting on 1st January 2005, IRA is not part of the Council of National Researches (CNR) anymore. The structure of IRA, as well as its territorial organization, has changed: it is now part of INAF, a much larger institute. In its constitution act, INAF is explicitly indicated as the national institute in charge of promoting, both at national and international levels, the activities related to astronomy, astrophysics and radioastronomy. The geodetic activity of IRA has been maintained within the new institute but the Geodetic division has changed location and structure. Though the reorganization process is not complete yet, new opportunities are foreseen in the process. The geodetic division within INAF has increased, joining the former IRA division with the former geodetic division of the Cagliari Astronomical Observatory. Within this new group, the coordination of geodetic activities involving Medicina and Noto telescopes seems to be very promising, also optimizing the efforts required for organizing and planning geodetic activities that are relevant for SRT (Sardinia Radio Telescope; http://www.ca.astro.it/srt/index.htm). SRT is now a project of INAF: this new institute is therefore managing three out of four radiotelescopes located on the Italian national territory. The year 2004 has therefore been very important in terms of reorganization and planning of the activity that will be carried out by our new group and by our new institute in the future.

2. Data Analysis and Results

The IRA started to analyze VLBI geodetic databases from 1989, using the CALC/SOLVE package on the HP1000 at the Medicina station. In the following years that software was installed on an HP360 workstation and later on an HP715/50 workstation. We have analyzed mostly databases with some European baselines, generally at least three. We are also storing all the databases of the Ny-Ålesund antenna. All hardware resources are now located at Bologna headquarters. These are two HP785/B2600 workstations and one HP282 workstation. We run CALC/SOLVE software package and f-SOLVE. During 2004, we have stored all the 1999-2004 databases available on the IVS data centers. All the databases have been processed and saved with the best selection of the parameters for the final arc solutions.

In 2004, we have also asked for OCCAM 6.0 software, which will be installed and used in 2005.

Our AC is participating in the IVS TROP Project on Tropospheric Parameters since the beginning of the activities. Submission of tropospheric parameters (wet and total zenith delay, horizontal gradients) of all IVS-R1 and IVS-R4 24hr VLBI sessions is regularly performed in form of SINEX files. Moreover, we imported and analyzed all the other 2000-2004 databases available on the IVS data centers, in order to compute the tropospheric parameters. We are carrying out a comparison between the VLBI tropospheric estimates and the GPS-derived troposphere for the co-located sites. Long time series of troposphere parameters have been computed using all VLBI sessions available in our catalogue, in order to estimate the behaviour of the content of water vapour in the atmosphere over time. We submitted long time series of tropospheric parameters to IVS TROP Project.

3. Outlook

For the time being, our catalogue contains all experiments containing European stations and all sessions performed after 1998. It is our intention to upload and analyze all experiments performed in the previous years, thus completing the catalogue.

Along with f-SOLVE, it is our intention to start regular data analysis using OCCAM, thus producing solutions with two important VLBI software packages.

Furthermore, we are going to start a regular production of Earth Orientation Parameters with the purpose of preparing for regular submission to IVS.

Vienna IGG Special Analysis Center Annual Report 2004

Harald Schuh, Johannes Boehm, Robert Heinkelmann, Thomas Hobiger, Sonja Todorova

Abstract

In 2004 the Institute of Geodesy and Geophysics (IGG) at the Vienna University of Technology has continued its investigations in atmospheric research for geodetic VLBI. Among other items, it started the comparison and combination of long time series of tropospheric parameters within the IVS ("VLBI for climate studies"). So far, six analysis centers (ACs) have agreed to take part (four ACs already submitted). This will allow a robust combination of the tropospheric parameters and a reliable determination of trends and seasonal signals in the time series.

1. General Information

After a reorganization of the Vienna University of Technology, the IVS Special Analysis Center at the Institute of Geodesy and Geophysics (IGG) is part of the Faculty of Mathematics and Geoinformation. It is mainly engaged in atmospheric research (troposphere and ionosphere) and further development of the VLBI software package OCCAM (Titov et al., 2001 [4]).

Figure 1. **New members of the IVS AC at IGG, Vienna**. Robert Heinkelmann (left) has taken over the combination of tropospheric parameters, and Sonja Todorova is involved in ionospheric research.

2. Staff

Personnel at IGG associated with the IVS Special Analysis Center in Vienna are Harald Schuh (Head of the Research Unit Advanced Geodesy, member of the IVS Directing Board), assistant professor Johannes Boehm, and the research assistants Robert Heinkelmann, Thomas Hobiger (presently at Kashima Space Research Center / NICT), and Sonja Todorova. While Johannes Boehm and Robert Heinkelmann mainly concentrate on tropospheric research, Thomas Hobiger and Sonja Todorova focus on the ionosphere. They are supported by several student assistants.

3. Current Status and Activities

- **Modification of the VLBI software package OCCAM**
  Together with Oleg Titov (Geoscience Australia), chairman of the "OCCAM Group", and Volker Tesmer (Deutsches Geodätisches Forschungsinstitut, Germany), IGG is involved in the development of the OCCAM software. In particular, it is in charge of the classical least-squares approach using the Gauss-Markov model. In 2004, the estimation of short period Earth orientation parameters and of radio source coordinates were implemented in OCCAM.

- **IVS Tropospheric Parameters: IVS-TROP**
  Since the tropospheric parameters determined at IGG (Schuh and Boehm, 2003 [3]) became regular IVS products in July 2003, the composition and presentation has evolved. The combined solution now consists of data from eight IVS ACs using three different VLBI software packages. New contributors are the Institute of Applied Astronomy, St. Petersburg, Russia with an OCCAM software solution instead of the former QUASAR software solution and the Main Astronomical Observatory, Kiev, Ukraine using the STEELBREEZE package. The combination product is provided by the IVS Data Centers one month after the availability of each new session database. The most recent 10 combination solutions are now available in graphical form and with a detailed statistical report on the web page `http://www.hg.tuwien.ac.at/~ivstrop`. Error checks are applied and a warning message is sent to an AC in case of a "suspicious" contribution.

- **IVS Long Term Series of Tropospheric Parameters**
  The Long Term Series solution includes all 24h-sessions or full subset type of sessions. Up to now six IVS Analysis Centers have agreed to participate: BKG, CNR, IAA, GSF, MAO, and IGG as the coordinating center. Four IVS Analysis Centers already submitted varying numbers of tropospheric parameters. A graphical example for the comparison of long term tropospheric parameters can be found below. A strategy for the combination will be set up soon.

- **IVS Meteorological Surface Instrumentation: IVS-MET**
  Concerning the history of meteorological sensors at the IVS Network Stations, the current situation of meta data (change of sensors, height of the pressure sensor relative to the VLBI reference point, ..) was compiled and archived. The archives were checked for up-to-dateness and consistency with GPS-MET data. Another effort to fill the missing data has been launched. Because of the incompleteness of meta data the homogeneity of meteorological surface data can only be checked and synthesised by statistical methods.

- **Vienna Mapping Functions VMF**
  In addition to the symmetric Vienna Mapping Functions VMF (Boehm and Schuh, 2004 [1]) azimuth-dependent mapping functions VMF-2 were determined for CONT02. They show a considerable improvement in terms of baseline length repeatabilities. More information about the mapping functions based on data from the ECMWF (European Centre for Medium-Range Weather Forecasts) can be found at `http://www.hg.tuwien.ac.at/~ecmwf` .

- **VLBI as a tool to probe the ionosphere**
  As VLBI is a differential technique the observed ionospheric delays (proportional to total electron content - TEC) represent the differences of the behaviour of the propagation media

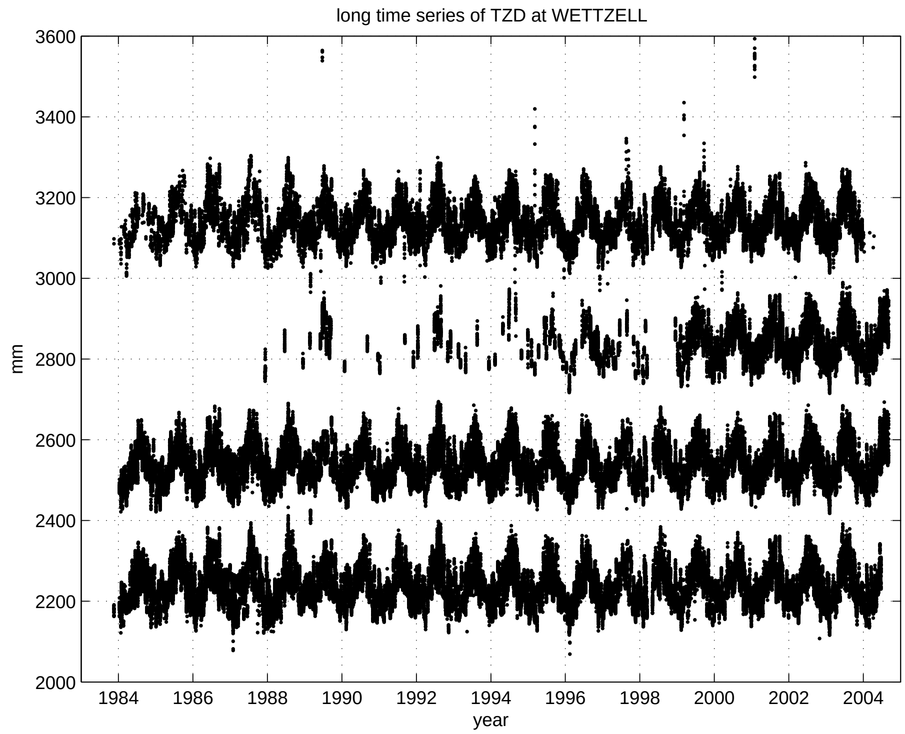


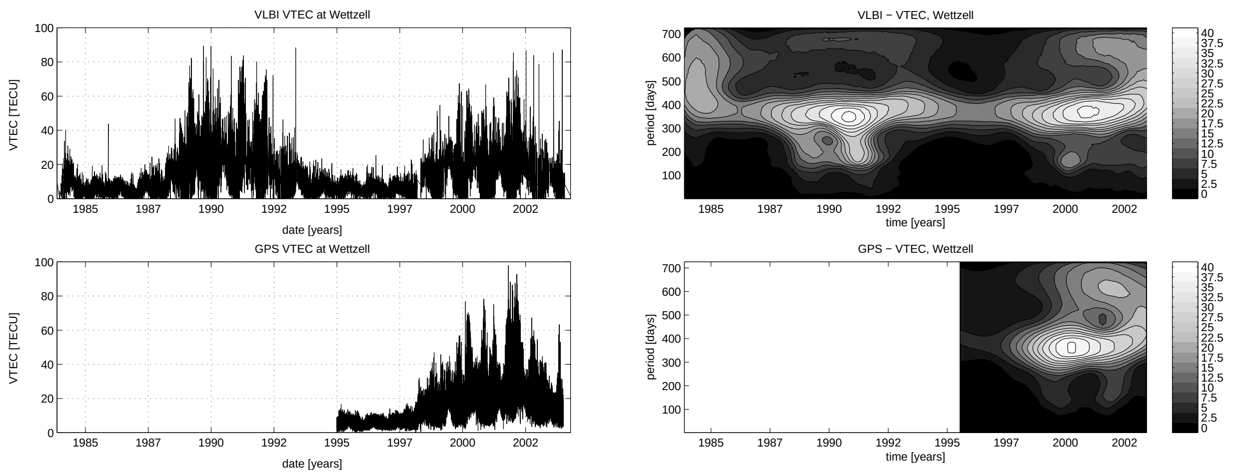
Figure 2. Total zenith delays in mm from IAO (+ 900 mm), CNR (+ 600 mm), BKG (+ 300 mm) and IGG.

above the two stations. Additionally an instrumental offset per station, independent of azimuth and elevation in which the antennas point, is contained in the observables. Due to the sparse geographical distribution of VLBI stations and the fact that this technique is not observing every day it is suggested to derive station-specific TEC values only. An appropriate algorithm developed at IGG [2] that deals with the special features of VLBI was applied to all available IVS database files. The results (e.g. Figure 3) can be used to validate the TEC values determined by other space geodetic techniques or they can be incorporated into long-term studies of the ionosphere, because VLBI observations cover already more than two complete solar cycles.

4. Future Plans

For the year 2005 the plans of the IVS Special Analysis Center at IGG include:

- Further development of OCCAM, e.g. the creation of complete SINEX output within OCCAM for the combination with other space geodetic techniques;
- Further research on azimuth-dependent mapping functions that are based on numerical weather models;
- Further improvement of ionopsheric parameters;
- Deriving combined 2D/3D global ionospheric models from GPS, satellite altimetry, and



VTEC in TECU from VLBI(top) and GPS (bottom) for station Wettzell.

Corresponding wavelet scalograms as derived from VLBI(top) and GPS (bottom) for station Wettzell.

Figure 3. VTEC values at station Wettzell from VLBI and GPS and their wavelet scalograms.

VLBI.

5. Acknowledgements

We are very grateful to the Austrian Science Fund (FWF) for supporting our work by research projects P16136-N06 and P16992-N10.
The authors want to thank the Japanese Society for the Promotion of Science, JSPS (project PE 04023) and Kashima Space Research Center, NICT for supporting Mr. Hobiger's research stay in Japan.

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JPL VLBI Analysis Center IVS Annual Report for 2004

Chris Jacobs

Abstract

This report describes the activities of the JPL VLBI analysis center for the year 2004. We continue to do celestial reference frame, terrestrial reference frame, earth orientation, and spacecraft navigation work using the VLBI technique. There are several areas of our work that are undergoing active development. In 2004 we demonstrated 1 mm level troposphere calibration on an intercontinental baseline. We detected our first X/Ka (8.4/32 GHz) VLBI fringes. We began to deploy Mark 5 recorders and to interface the Mark 5 units to our software correlator. We also have actively participated in the international VLBI community through our involvement in six papers at the February IVS meeting and by collaborating on a number of projects such as densifying the S/X celestial frame and creating celestial frames at K (24 GHz) and Q-bands (43 GHz).

1. General Information

The Jet Propulsion Laboratory (JPL) analysis center is located in Pasadena, California. Like the rest of JPL, it is operated by the California Institute of Technology under contract to NASA. JPL has had a VLBI analysis group since about 1970. Our work is focussed on supporting spacecraft navigation. This includes several components:

1. Celestial Reference Frame (CRF) and Terrestrial Reference Frame (TRF) are efforts which provide infrastructure to support spacecraft navigation and Earth orientation measurements.
2. Time and Earth Motion Precision Observations (TEMPO) measures Earth orientation parameters based on single baseline semi-monthly measurements. These VLBI measurements are then combined with daily GPS measurements as well as other sources of Earth orientation information. The combined product is used to provide Earth orientation for spacecraft navigation use.
3. Delta differenced one-way range (ΔDOR) is a differential VLBI technique which measures the angle between a spacecraft and an angularly nearby extragalactic radio source. This technique thus complements the radial information from spacecraft doppler and range measurements by providing plane-of-sky information for the spacecraft trajectory.

2. Technical Capabilities

The JPL analysis center acquires its own data and supplements it with data from other centers. The data we acquire is taken using NASA's Deep Space Network (DSN).

1. Antennas: Most of our work uses 34m antennas located near Goldstone (California, USA), Madrid (Spain), and Tidbinbilla (Australia). These include the following Deep Space Stations (DSS): the "High Efficiency" subnet comprised of DSS 15, DSS 45, and DSS 65 (see Figure 1) which has been the most often used set of antennas for VLBI. More recently, we have been using the DSN's beam waveguide (BWG) antennas: DSS 13, DSS 24, DSS 25, DSS 26, DSS 34, DSS 54, and DSS 55. Less frequent use is made of the DSN's 70m network (DSS 14, DSS 43, DSS 63). Typical X-band system temperatures are 35K on the HEF antennas. The 70m and BWGs are about 20K. Antenna efficiencies are typically well above 50% at X-band.

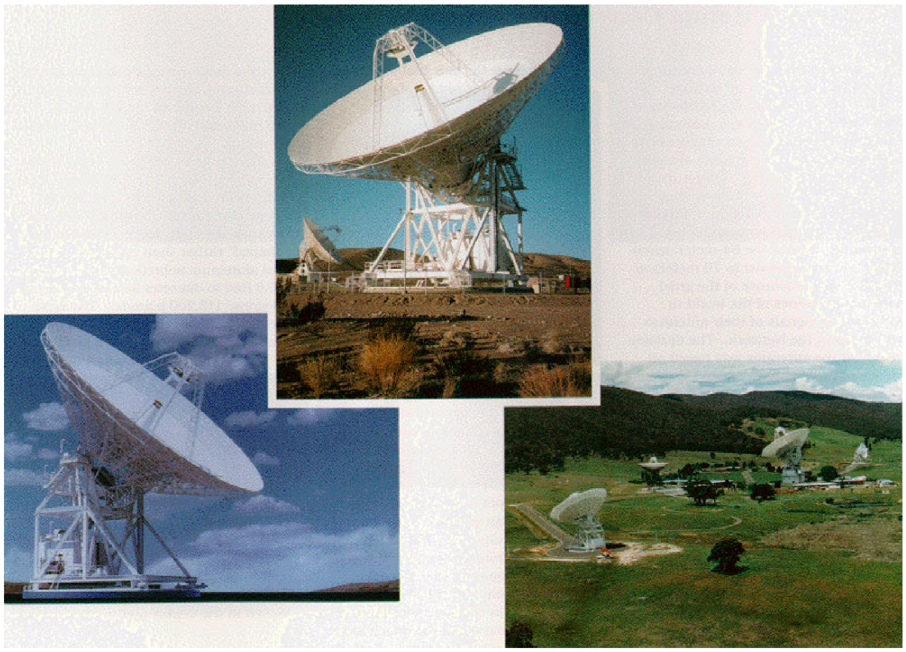

Figure 1. This figure shows the three high-efficiency antennas in the subnet: Goldstone is in the center; Robledo, Spain is in the lower left; and Tidbinbilla, Australia is on the lower right. These antennas were designed to have an optimum efficiency at X-band (8.4 GHz), which was to become the standard downlink frequency for solar-system exploration. An important secondary objective was to have a reasonable efficiency at Ka-band (32 GHz) thereby allowing for possible future use at the next highest band allocated for deep space communications. The subnet was completed in 1986 in time for the Voyager encounter with Uranus.

2. Data acquisition: The DSN sites have standard Mark IV VLBI data acquisition systems. We are just completing the installation of Mark 5 recorders. In addition we have a JPL-unique system called the VLBI Science Recorder (VSR) which has digital "video converters" and records directly to hard disk. The data is later transferred via network to JPL for correlation processing.
3. Correlators: The JPL BlockII VLBI correlator handles the TEMPO and CRF correlations of Mark IIIa format tapes. The ΔDOR data from the VSR systems are correlated using the SOFTC software correlator running on UNIX or VMS workstations. The VSRs and the software correlator have also been used for connected element interferometry tests of antenna arraying concepts in preparation for arraying large numbers of smaller ($\approx$ 12 m) antennas.
4. Solution types: We run several different types of solutions. For ΔDOR spacecraft tracking we make narrow field ($\approx 10^\circ$) differential solutions. The TEMPO solutions typically have a highly constrained terrestrial (TRF) and celestial frame (CRF) as a foundation for estimating Earth orientation parameters. These reference frames are produced from global solutions which then provide the framework needed for use by TEMPO and ΔDOR.

3. Staff

Our staff are listed below with a brief indication of areas of concentration within the VLBI effort at JPL. Note that not all of the staff listed work on VLBI exclusively as our group is involved in a number of projects in addition to our VLBI work.

- Jim Border: ΔDOR
- Sid Dains: Field support of VLBI experiments at Goldstone.
- Chris Jacobs: CRF and TRF
- Peter Kroger: ΔDOR
- Gabor Lanyi: VLBA phase referencing, ΔDOR, WVR, CRF, and TRF.
- Steve Lowe: Software correlator, fringe fitting software
- Walid Majid: ΔDOR
- Chuck Naudet: WVR, Mark IV support, and CRF
- Ojars Sovers: CRF and TRF. Maintains MODEST analysis code.
- Alan Steppe: TEMPO and TRF.
- L.D. Zhang: CRF and TEMPO.

4. Current Status and Activities

In preparation for the 2005 Mars mission, JPL is leading a collaboration with Goddard Space Flight center, the U.S. Naval Observatory, National Radio Astronomical Observatory, and the Bordeaux Observatory to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz) (*e.g.* Jacobs *et al*, 2004).

A-WVR: The advanced Water Vapor Radiometer (A-WVR) developed for the Cassini gravitational wave experiment, continues to be used in research applications. This device can calibrate water vapor induced delays with fractional stability of roughly a few parts in 10^{15} over time scales of 2,000 to 10,000 seconds. In 2004, we used the A-WVR to demonstrate a factor of three reduction in VLBI residuals on time scales of 100 to 1000 seconds.

5. Future Plans

We are also in the planning stage for developing a Ka-band (32 GHz) realization of the ICRF. All this work is motivated by the anticipation that spacecraft navigation will require a 32 GHz reference frame within a few years.

Mark 5 recorders: In 2004 we began integrating Mark 5 hard disk recording systems into the Deep Space Network.

6. Acknowledgements

The research described in this paper was in part performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

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IVS Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine

Sergei Bolotin, Yaroslav Yatskiv

Abstract

This report summarizes the activities of VLBI Analysis Center at Main Astronomical Observatory of National Academy of Sciences of Ukraine in 2004.

1. Introduction

The VLBI Analysis Center was established in 1994 by Main Astronomical Observatory (MAO) of the National Academy of Sciences of Ukraine as a working group of the Department of Space Geodynamics of MAO. In 1998 it started its IVS membership as an IVS Analysis Center. The AC MAO is located in Central building of the observatory in Kiev.

The primary goal of the activity of the Center is the development of the VLBI data processing software SteelBreeze. In 2004 we submitted VLBI data analysis results to IVS.

2. Technical Description

The computer of the Analysis Center is a Pentium-4 1.9 GHz CPU box with 256M RAM and a 160 Gb HDD. It is running under Linux/GNU Operating System and is used for software development and VLBI data processing.

Main Astronomical Observatory has a 256 kbps link for Internet connection.

The SteelBreeze software is written in the $C++$ programming language and uses Qt widget library. SteelBreeze makes Least Squares estimation of different geodynamical parameters with the Square Root Information Filter (SRIF) algorithm (see [1]).

The software analyzes VLBI data (time delay) of single and multiple sets of sessions. The time delay is modeled according to the IERS Conventions (2003) [2], plus additional models (tectonic plate motion, nutation models, wet and hydrostatic zenith delays, mapping functions, etc). The software makes estimations of the following parameters: Earth orientation parameters, coordinates and velocities of a selected set of stations, coordinates of a selected set of radio sources, clock function and wet zenith delay.

3. Staff

The VLBI Analysis Center at Main Astronomical Observatory consists of two members:

Prof. Yaroslav Yatskiv: Head of the Department of Space Geodynamics, performs general coordination and support of activity of the Center.

Ph.D. Sergei Bolotin: Senior research scientist of the Department of Space Geodynamics, responsible for the software development and data processing.

4. Current Status and Activities in 2004

In 2004 we performed regular VLBI data analysis to determine Earth rotation parameters. This "operational" solution is produced and submitted to IVS on a weekly basis. The IERS Conventions (2003) [2] models have been applied in the analysis. In this solution coordinates of stations and Earth rotating parameters are estimated.

In addition, this year we started to participate in the IVS Tropospheric Parameters project. Estimated wet and total zenith delays for each station are submitted to IVS. The analysis procedure is similar to previous one.

5. Plans for 2005

MAO Analysis Center will continue to take part in operational EOP determination as well as updating the solutions of TRF and CRF from VLBI analysis of full dataset of observations.

The development of the software SteelBreeze will be continued next year also.

Acknowledgments

The work of our Analysis Center would be impossible without activities of other components of IVS. We are grateful to all contributors of the Service.

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Analysis Center at National Institute of Information and Communications Technology

Ryuichi Ichikawa, Mamoru Sekido, Hiroshi Takeuchi, Yasuhiro Koyama, Thomas Hobiger, Tetsuro Kondo

Abstract

This report summarizes the activities of the Analysis Center at National Institute of Information and Communications Technology (NICT, former CRL) for the year 2004. By using the state-of-art e-VLBI systems, we performed the international EOP session between Westford and Kashima, differential VLBI measurements for the precise tracking the spacecraft HAYABUSA and geodetic experiments. In particular, we achieved the most rapid estimation of UT1-UTC with a latency of four and half hours. In addition, we performed ionospheric studies, the development of automatic GPS data processing system, and satellite communication experiments.

1. General Information

The NICT analysis center is located in Kashima, Ibaraki, Japan. It is operated by the Radio Astronomy Applications Group, Kashima Space Research Center of NICT. VLBI analyses at NICT are mainly concentrated on experimental campaigns for developing new techniques such as e-VLBI measurements for the real-time EOP determination and differential VLBI (DVLBI) for spacecraft orbit determination. In addition we carried out monthly IVS-T2 sessions, the feasibility experiment of GPS and VLBI data transmission using a TCP/IP satellite communication link. We are also developing an automatic GPS analysis system named “APPS (Advanced Precise Positioning System)” to provide the precise positioning for non-geodesist users.

2. Staff

The staff members who are contributing to the Analysis Center at the NICT are listed below (in alphabetical order):

- ICHIKAWA R., Development of data analysis software for the DVLBI and atmospheric modeling.
- KONDO T., Responsible for overall operations and performance.
- KOYAMA Y., Development of data analysis software for the geodetic experiment.
- SEKIDO M., Development of data analysis software for the DVLBI.
- TAKEUCHI H., Development of distributed processing system.
- T. HOBIGER, Analysis of ionospheric effects on space geodesy.

3. Current Status and Activities

3.1. Real-time EOP measurements

On June 29, 2004, one hour e-VLBI session between Westford and Kashima stations was performed to obtain UT1 estimation as soon as possible [1]. After the observations, the data recorded at Westford station with the Mark 5 system were extracted and transferred to Kashima through Abilene/TransPAC/JGNII networks. 13.5 GBytes of data were transferred in about 1 hour and 15 minutes and the average data transfer rate was 24 Mbps. The transferred data were then converted to the K5 file format. As soon as the data format conversion was completed, the software correlation was started using both NFS-based distributed processing system on Linux and FreeBSD and the VLBI@home on Windows 2000 and XP [2]. Immediately after all the correlation processing was completed, database files were generated and the data analysis was performed by using CALC and SOLVE software developed by the Goddard Space Flight Center of NASA. The data analysis was completed in about 4 hours and 30 minutes after the last observation of the session. Table 1 shows the time sequence from the observations.

Table 1. Time sequence from observations through the data analysis of the e-VLBI session on June 29, 2004

Events	Time in UT (Date)
Observing session started	19:00 (June 29)
Observing session finished	20:00
File transfer started	20:13
File transfer completed	21:28
Correlation processing completed	00:16 (June 30)
Data analysis completed	00:30

Following the success, an extra intensive session series between Tsukuba and Wettzell that observes every Sunday was initiated to fill the remaining day of the week for the intensive sessions. By establishing the Sunday intensive sessions, UT1 estimation from VLBI observations have become possible everyday.

3.2. Differential VLBI

We performed VLBI experiments for tracking the HAYABUSA spacecraft. HAYABUSA, which means “Falcon” in Japanese, was launched on May 9, 2003, and has been flying steadily towards an asteroid named “Itokawa”, after the late Dr. Hideo Itokawa, the father of Japan’s space development program. The first HAYABUSA VLBI experiment was performed at X-band (8.4 GHz) using six VLBI stations in Japan on November 26, 2003.

We also performed HAYABUSA VLBI experiment on October 16 and 18, 2004 in order to evaluate reduction of propagation delays due to the ionosphere and neutral atmosphere using differential VLBI technique. In this experiment, we acquired the VLBI data using both K5 system and state-of-art Gigabit system. The hybrid correlation processing based on the Gigabit system and the DBBC (Digital Baseband Converter) filtering technique is very efficient to detect fringes of weak radio sources which have small separation angle from the spacecraft [2].

3.3. Ionospheric Study

Mr. Hobiger (research fellow of the Japan Society for the Promotion of Science (JSPS) since July 1st, 2004) was conducting research on the determination of ionospheric parameters from VLBI observations. He has enhanced a method, first developed at NICT (Kondo, 1991, [4]), to

According to the comparison between group delays and R&RR results, large residuals of more than 100 nanoseconds have been found as shown in Figure 1[3].

The large scattering of the group delays is shown at the first four epochs and after about 07:30UT in Figure 1. On the other hand, the relatively small scattering, less than 10 nanoseconds, is shown during the period between 05:00UT and about 07:30UT. It is considered that the difference is caused by the characteristic of the radio signals transmitted from HAYABUSA. The group delays with large residuals are obtained using the telemetry signal, which has narrow bandwidth less than 1 MHz. The other group delays are obtained by the range signal which has a bandwidth of more than 1.5 MHz.

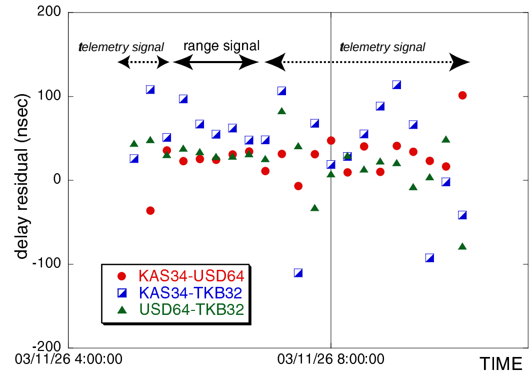

Figure 1. Residual delays between determined position using R&RR data by ISAS/JAXA and VLBI group delay observables

gain absolute ionospheric values from dual frequency VLBI measurements and applied it to the whole IVS database and several other data sources. The results may validate existing theoretical or measurement-based ionospheric models. Furthermore his studies provide useful information about long-term trends in the ionosphere ([5]) and allow direct comparison to results from other space geodetic techniques, like GPS or satellite altimetry missions. Moreover he is investigating effects on ionospheric corrections caused by the receiving system and by correlation processes.

3.4. Geodetic Data Transmission Through the Satellite TCP/IP Link

Full-time observations at globally distributed VLBI stations are desirable for real-time monitoring of the earth orientation. However, pacific and southern hemisphere coverage is not sufficient. If we are able to use a high speed TCP/IP data link using an optical fiber network or wideband satellite communication at the South Pacific Islands, the state-of-art e-VLBI system, which we are developing, will be able to fill a gap in the VLBI observation network. Thus, we started to perform satellite data transmission experiments[6].

Our first experiments were successfully carried out during the periods of February 9-14, 2004 and January 16-21, 2005 at the University of South Pacific (USP), SUVA, Fiji. In the 2004 experiment we evaluated the throughput rate using the new satellite router which can improve the maximum throughput of a TCP connection to avoid the time delay due to the round trip time (RTT). The peak data throughput was slightly more than 1440 Kbps, which is up to about 94% of the nominal maximum throughput. In the 2005 experiment we successfully performed the K5 software correlation of VLBI data sets using the VLBI@home between Japan and Fiji via satellite link.

3.5. APPS

We are developing an automatic GPS analysis system named “APPS (Advanced Precise Positioning System)”. APPS enables everybody to obtain accurate GPS solutions without requiring geodetic understanding, the operation of the sophisticated GPS software, or complicated data handling. Users can submit static single point or multi-station network GPS data to the APPS analysis server by e-mail and receive the analyzed results back by e-mail after a few minutes. At present we allow access to the mail-based APPS analysis server only to a limited number of users in order to help to revise the system and we are developing the web site service of APPS.

3.6. Evaluation of Atmospheric Model

Observations of atmospheric slant delay using water vapor radiometer (WVR) near the Kashima 34-m antenna continue for detecting and characterizing water vapor variations. We are also evaluating atmospheric parameters (equivalent zenith wet delay and linear horizontal delay gradients) and positioning errors derived from slant path delays obtained by ray-tracing through the non-hydrostatic numerical weather prediction model (NHM) with 1.5 km horizontal resolution.

4. Future Plans

For the year 2005 the plans of the Analysis Center at NICT include:

- Several international and domestic VLBI experiments for the real-time EOP determinations using the e-VLBI and K5 system (both IP-VLBI system and PC/VSI system).
- Differential VLBI experiments for spacecraft tracking
- Development of the analysis software for the spacecraft positioning using phase delay observables
- Improvement of the processing speed and efficiency of the VLBI data correlation using multiprocessor and high speed network
- Evaluation of simulated positioning errors due to the tropospheric parameters derived from the non-hydrostatic numerical weather prediction data.

In addition KSP data sets are still available at the URL http://ksp.nict.go.jp/index.html. General information about VLBI activities at the NICT is provided at:

http://www2.nict.go.jp/ka/radioastro/index.html

(Please note that these URLs were changed from those given in the 2003 annual report).

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Paris Observatory Analysis Center OPAR: Report on Activities, January - December 2004

A.-M. Gontier, M. Feissel-Vernier, C. Barache

Abstract

In preparation for the evolution of the definition of the VLBI-based International Celestial Reference Frame (ICRF), we studied the consequences of the status of the terrestrial reference frame in the data analysis, using a set of selected stable radio sources ([2]). We conclude that estimating both the celestial and the terrestrial reference frames in the VLBI global analysis does not impact the quality of the celestial reference frame, and that the use of observations of the proposed set of stable sources collected since 1990 would allow an improvement by a factor of four in the maintenance of the ICRF axes, to reach 5 μas, and by a factor of eight in the source position precision, to reach 30 μas. We also show that the impact of the source selection on the determination of the sidereal orientation of the Earth may reach 300 μas for some low frequency components.

1. Sensitivity of the Celestial Reference Frame to the Terrestrial Reference Frame Status in the Data Analysis

The analysis strategies for deriving a celestial reference frame from multi-year VLBI observations include a number of choices. We consider here the choice that has to be made concerning the definition of the celestial and terrestrial reference frames and their connection in time. Two different approaches are used, as follows. In the derivation of the ICRF and its extensions (Ma et al. [6], Fey et al. [5]), the so-called **CRF** approach was used, namely the stations' positions are set as *arc parameters*, i.e., they are estimated independently for each observing session. In the so-called **TRF** approach, most station positions and velocities are set as *global parameters*, i.e. considered as valid over the total data span.

The **CRF** approach was chosen by the authors of ICRF in order to free the celestial frame solution from systematic errors that may be propagated from terrestrial network deficiencies. We investigated the possible contamination using test solutions based on the 1980.0-2002.7 data, described in Table 1. Data analysis was performed with the CALC-SOLVE software package. The details of the study will be available in [4].

Table 1. Test solutions: status of the sources (Global or Arc) and category of sources considered to define the orientation of the frame (No-net-rotation, NNR).

Frame	Arc srces	Globl srces	NNR	Frame	Arc srces	Globl srces	NNR
TRF approach				**CRF** approach			
cne	unstable	all others	stable	*cnh*	unstable	all others	stable
cn7	none	all	ICRF *defining*	*cn8*	none	all	ICRF *defining*

1.1. Impact on the Orientation of the Celestial Reference Frame

In order to test the possible perturbation of the orientation of the celestial reference frame due to the consideration of a global terrestrial frame, i.e. one set of station positions and velocities, we compute the relative orientations of pairs of celestial frames obtained with the same source categorization, with the **TRF** and the **CRF** approach. The relative orientation of two celestial reference frames is modelled by three rotation angles A_1, A_2, A_3 around the axes of the equatorial coordinate system. These angles are estimated together with the dz parameter, modelling an apparent equator that reflects systematic differences in declination. The relative angles between pairs of celestial reference frames are given in Table 2, for the two pairs of celestial frames described in Table 1. In the case of the conventional source selection (cn7 and cn8), the inconsistency of the axes definition between the **TRF** and **CRF** approaches is smaller than 8 μas, which is well under the published accuracy of the ICRF axes (20 μas). In the case of the selection of stable sources (cne and cnh), it is even smaller (less than 3 μas).

Table 2. Relative rotation angles and equator tilt of celestial reference frames obtained with the **TRF** and **CRF** approaches. Unit: μas.

Pair	A_1	A_2	A_3	dz
Reference sources: Stable ones				
cne-cnh	0.7 ± 0.6	0.2 ± 0.6	-2.3 ± 0.6	0.5 ± 0.9
Reference sources: *Defining*				
cn7-cn8	-6.9 ± 1.0	6.6 ± 1.0	1.7 ± 1.4	-4.2 ± 1.4

1.2. Impact on the Precision of the Celestial Reference Frame

To evaluate the impact of the **TRF** approach on the precision of the source positions, we compare them with two independent celestial frames available at the IERS/ICRS Product Center and that were provided by the IAA and the BKG, respectively. Note that the *cne* and *cnh* frames of Table 1 were aligned onto the ICRS axes using an NNR condition based on the 199 stable sources, while for the *cn7*, *cn8* and the two independent frames, the NNR condition was based on the 212 ICRF *defining* sources. The analysis strategy used to derive the independent celestial reference frames follows the **TRF** approach.

In each comparison, the two frames are rotated to common axes in a least squares adjustment applied to the 206 sources that are common to all reference frames. The variances of the postfit residuals $\Delta\alpha cos\delta$ and $\Delta\delta$ are computed. The three-cornered-hat method is then applied to these variances to derive the individual standard deviations for the reference frames of Table 1, listed in Table 3. The robustness of the estimations was tested by associating the data in various ways. The results remain stable within 2 μas. In the case of the conventional source selection as well as in that of the selection of stable sources, we conclude from the values of Table 3 that the impact on the precision of the source positions is smaller than 3 μas.

2. Terrestrial Reference Frame Status and the Measurement of Precession and Nutation

The computation of the test celestial frames included the estimation of the celestial pole offsets $\Delta\psi$ and $\Delta\epsilon$ for each session, considering only the global sources. These time series are compared to the prediction of the IAU2000 nutation model. Note that the latter was obtained by Mathews et al. ([7]) starting from an analysis of VLBI observations where all sources were considered global,

Table 3. Standard deviations of source positions for celestial reference frames derived by the TRF and CRF approaches. Unit: μas

Source selection	**TRF** approach Standard deviations			**CRF** approach Standard deviations		
	sol.	$\Delta\alpha cos\delta$	$\Delta\delta$	sol.	$\Delta\alpha cos\delta$	$\Delta\delta$
Proposed	*cne*	27.1	21.2	*cnh*	28.0	21.1
Convent.	*cn7*	28.2	27.5	*cn8*	29.4	24.7

and using a source selection scheme analogous to that leading to celestial frames *cn7* or *cn8*.

The parameters investigated are precession and obliquity rate corrections, and corrections to the 18.6-year nutation, estimated over the 1984.0-2004.7 time span.

2.1. Precession, Obliquity Rate and 18.6-year Nutation

The estimations of precession and obliquity rate corrections from the four data sets under study are listed in Table 4. As already noted by Dehant et al. ([1]) and Feissel-Vernier et al. ([3]), the impact of the source selection, i.e. *cne* vs *cn7* or *cnh* vs *cn8*, is at the level of 40-50 μas/year in precession, while it is small on the obliquity rate. Compared to that effect, the impact of the terrestrial frame status, i.e. *cne* vs *cnh* or *cn7* vs *cn8* (2 μas), is barely significant.

The estimations of the 18.6-year nutation corrections are also listed in Table 4. The same remarks apply: while the impact of the source selection is quite large (up to 50 μas in $\Delta\psi sin\epsilon_0$), the impact of the terrestrial frame status (10 μas) is statistically insignificant.

Table 4. Precession, obliquity rate and 18.6-year nutation corrections: role of the terrestrial reference frame status and of the source selection

Source selection	Precession μas/year	Obliqu. rate μas/year	18.6-yr $\Delta\psi$ (μas) sine	18.6-yr $\Delta\psi$ (μas) cosine	18.6-yr $\Delta\epsilon$ (μas) sine	18.6-yr $\Delta\epsilon$ (μas) cosine
TRF approach						
Proposed (*cne*)	-56.3 ± 4.8	-31.6 ± 1.8	252 ± 23	150 ± 26	-12 ± 9	19± 10
Conventional (*cn7*)	-17.6 ± 4.2	-28.5 ± 1.7	80 ± 20	163 ± 24	-46 ± 8	31± 10
CRF approach						
Proposed (*cnh*)	-58.2 ± 4.6	-32.4 ± 1.7	266 ± 22	135 ± 25	-6 ± 8	19 ± 9
Conventional (*cn8*)	-15.4 ± 4.0	-27.0 ± 1.6	71 ± 19	139 ± 23	-47 ± 7	39 ± 9

2.2. Residual Noise

Statistics of the residual noise in the comparisons of VLBI series of $\Delta\psi$ and $\Delta\epsilon$ with the IAU2000 model are shown in Table 5. Compared to the **CRF**-type solutions, the level of the residual noise of the **TRF**-type solutions, is larger by less than 5%. We therefore may consider that the difference in treating the station coordinates only slightly affects the high frequency noise of the nutation determinations.

Table 5. Agreement of the IAU2000 Precession-Nutation model, corrected for a bias and the terms listed in Table 4, with VLBI results derived with various analysis approaches. Unit: μas

Reference frame	**TRF** approach Standard Dev. (μas)			**CRF** approach Standard Dev. (μas)		
		$\Delta\psi sin\epsilon_0$	$\Delta\epsilon$		$\Delta\psi sin\epsilon_0$	$\Delta\epsilon$
Proposed	*cne*	254	239	*cnh*	244	229
Convent.	*cn7*	236	239	*cn8*	228	233

3. Sidereal Orientation of the Earth and Stability of the VLBI Celestial Reference Frame

The impact of the source selection on the estimation of precession and nutation components was investigated over the time span 1984-2002 ([3]). The precession correction to the IAU2000 value that is obtained when excluding the unstable sources reaches 49 $\pm$ 5 μas/year, to be compared to 12 $\pm$ 5 μas/year using the current conventional celestial frame. The determination of the obliquity rate is unaffected and remains at the level of 27 $\pm$ 2 μas/year. The observed correction to the 18.6-year nutation amplitude using the current conventional celestial frame are sizeably corrupted by the unstable sources. After accounting for this effect, the estimations relative to both sets of reference radio sources confirm a discrepancy with the IAU2000 nutation model with a total amplitude of 320 $\pm$ 100 μas for the observed nutation in longitude, to be compared to the 80 μas discrepancy found by Mathews et al. ([7]). The discrepancy in obliquity amounts to 50 $\pm$ 16 μas. The effect of source instability is shown to have an impact on the determination of universal time at the one microsecond level. The high and medium frequency nutation terms (up to periods of a few years) are impacted only in the early years of the program.

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The IVS Analysis Center at the Onsala Space Observatory

Rüdiger Haas, Hans-Georg Scherneck

Abstract

We shortly summarize the activities of the IVS Analysis Center at the Onsala Space Observatory during 2004. Examples of achieved results and ongoing analyses are presented.

1. Introduction

The work of the IVS Analysis Center at the Onsala Space Observatory (OSO) focusses on a number of particular research topics that are relevant to space geodesy and geosciences. Data obtained from geodetic VLBI observations and from complementing techniques form a basis to address these topics. During 2004 the main focus was on earth rotation, loading phenomena, and propagation of radiowaves through ionosphere and atmosphere. Some of the results are presented in the following. For the future we plan to continue concentrating on particular research topics.

2. High-frequency EOP Variations During CONT02

During 2004 we continued the earlier reported analysis [1] of the CONT02 VLBI observations with respect to high-frequency variations in polar motion and UT1. Various signal analysis tools were applied in the data analysis, ranging from spectral estimation to wavelet analysis. Figure 1 shows wavelet scalograms of retrograde and prograde polar motion during CONT02. Besides the well known daily and semi-diurnal polar motion variations also energy in the ter-diurnal frequency band at about 8 hours period could be detected [2]. Further investigations concerning the source of these ter-diurnal variations are ongoing.

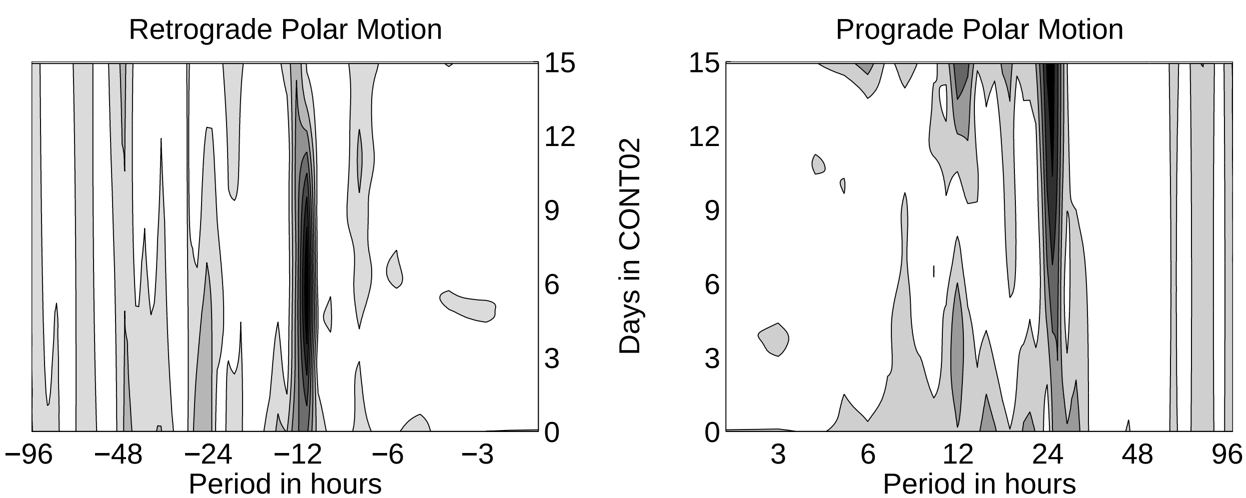

Figure 1. Wavelet scalograms of retrograde (left) and prograde (right) polar motion derived from CONT02 data. The normalized wavelet energy is shown in grey-scale, where dark colors mean high energy.

3. Ocean Tide Loading and Atmospheric Loading

The service provided by the automatic ocean tide loading provider [3] has been maintained and extended during 2004. The TPXO.6.2 ocean tide model [4] was added, and the website http://www.oso.chalmers.se/~loading now offers 14 different ocean tide models that are available to calculate ocean tide loading parameters. The users can interactively enter the site positions for which the parameters shall be calculated and receives the results via email. Several data formats for the results are available.

The time series of atmospheric loading predictions were updated to cover the year 2004. As before they are based on global convolution of atmopheric pressure fields sampled at $1^o \times 1^o$ resolution and the synoptic 6h intervals. They are available for most of the VLBI databases since 1990 on the website http://www.oso.chalmers.se/~hgs/apload/apload.html.

4. Ionospheric Studies Using VLBI data

We developed a method to determine maps of total electron content (TEC) from VLBI data using a spherical harmonics approach. This method was successfully tested with data observed with several geodetic VLBI networks, and the results were compared to TEC-maps derived from GPS [5]. The agreement with respect to GPS TEC-maps is on the order of 10 TEC units. Figure 2 shows the TEC-maps derived from the VLBI data of the CONT02 campaign.

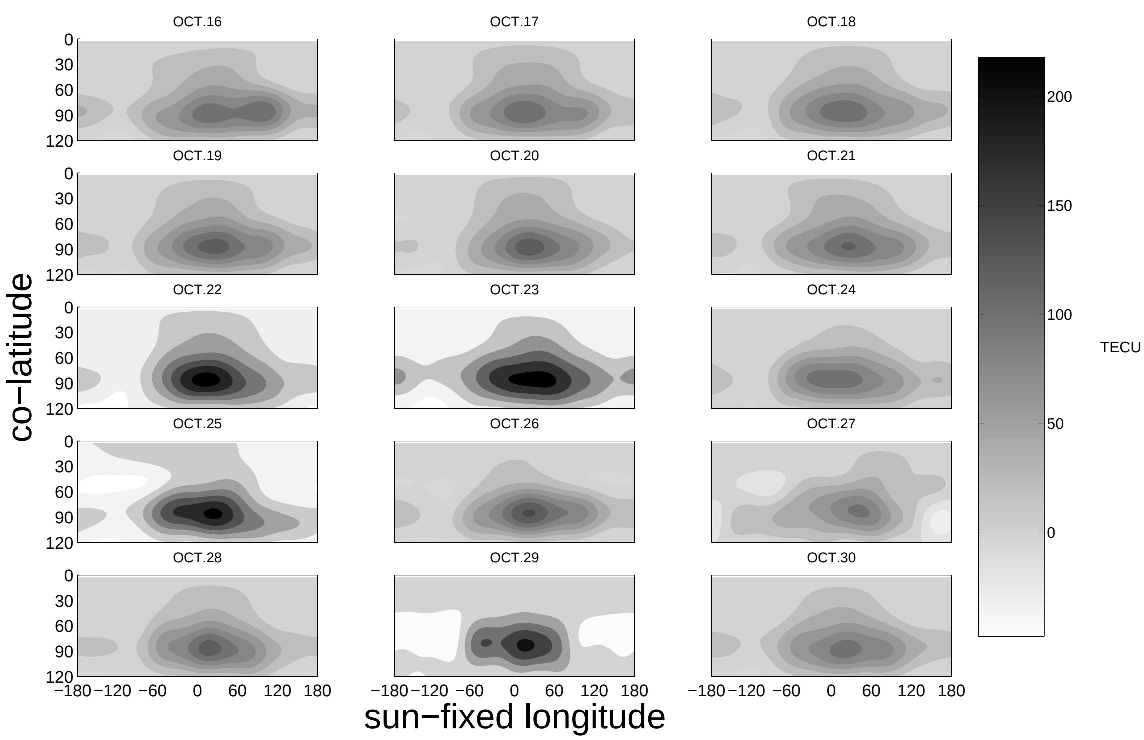

Figure 2. TEC-maps derived from VLBI data of the CONT02 campaign in October 2002.

5. Mapping Functions From High Resolution Numerical Weather Models

We investigated the possibility of using high resolution numerical weather prediction models for the determination of mapping functions. In this context, we developed a method to derive mapping functions from the HIRLAM model. This model has the advantage of high spatial and temporal resolution [6]. The HIRLAM based mapping functions were tested with VLBI data observed in the year 2000 and a slight improvement in baseline repeatability was detected, compared to analysis solutions with other state of the art mapping functions [7].

6. Trends in Tropospheric Water Vapor at Onsala

The investigation of trends in tropospheric water vapor at Onsala [8] was continued. Figure 3 shows time series of integrated precipitable water vapor (IPWV) derived from collocated VLBI, GPS and WVR at Onsala and radiosondes launched at the Landvetter airport 37 km away from the observatory. Various analysis strategies, combination and integration approaches were investigated.

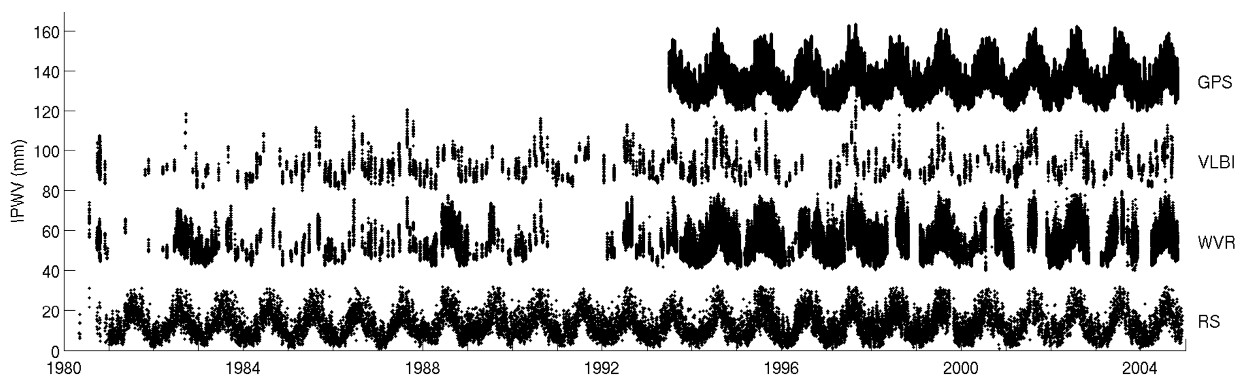

Figure 3. Time series of integrated precipitable water vapor (IPWV) derived from the collocated techniques VLBI, WVR and GPS at Onsala and radiosondes (RS) launched at Landvetter airport.

7. Participation in the IVS TROP Project

We continued our activity in the IVS TROP Project by submitting tropospheric parameters for all VLBI stations observing in the IVS R1 and R4 networks to the IVS on a regular basis. Figure 4 shows histograms of the gradient results of four IVS stations located in different hemispheres and climatic zones: Ny-Ålesund – northern hemisphere/polar, Wettzell – northern hemisphere/temperate, HartRAO – southern hemisphere/dry, Fortaleza – equatorial/tropical. The histograms include results from the IVS R1 and R4 experiments during 2002 and 2004. Some dependence of the magnitude and sign of the gradients on the location of the station appears to be detectable.

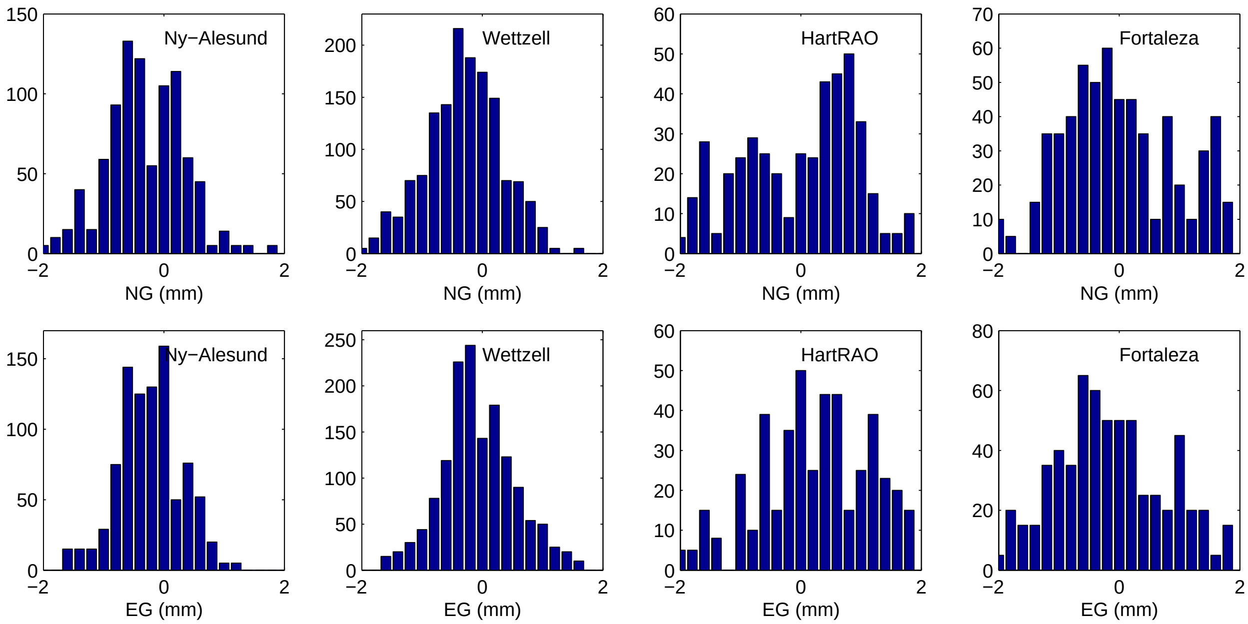

Figure 4. Histograms of North gradients (upper row) and East gradients (lower row) for IVS stations located in different hemispheres and climate regions. The histograms include results from the IVS R1 and R4 experiments during 2002 and 2004.

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Shanghai Astronomical Observatory Analysis Center 2004 Annual Report

Jinling Li

Abstract

Our research activities in 2004 mainly focused on satellite positioning and orbit determination by VLBI. We were also involved in the coordination of VLBI experiments, data archives, reduction and application studies. The plan for the next year is to continue our efforts in the application studies of VLBI. We are also planning to contribute to IVS the quarterly solutions of Earth Orientation Parameters.

1. General Information

As one of the research groups of the Center for Astrogeodynamics Research, Shanghai Astronomical Observatory (SHAO), we focus our activities on studies of Radio Astrometry and Celestial Reference Frames. Facilities for us to analyze the astrometric and geodetic VLBI observations are the HP C180 workstation, several sets of personal computers with advanced technical specifications, as well as several sets of SUN workstations in the computer division of SHAO. We use CALC/SOLVE system in the routine VLBI data reduction. The members involved in the IVS activities are Jinling Li, Guangli Wang, Bo Zhang, Li Guo, Nianchuan Jian, Ming Zhao and Zhihan Qian.

2. Current Activities

2.1. Observation Coordination and Data Reduction

In September of 2004 two new 24hour VLBI sessions of the Asia-Pacific Space Geodynamics (APSG) program were carried out. Up to now there are in total 15 APSG sessions with single solution $wrms$ about $40ps$. We also participated in some IERS/IVS campaigns aimed at comparisons of reference frames and/or Earth Rotation Parameters.

2.2. Solutions and Analysis of High Frequency Variation of ERP

The time series of Earth Rotation Parameters (ERP, UT1-UTC, x and y) with two hour resolution from 1980 to 2003 are solved by performing global solutions of thousands of astrometric and geodetic VLBI sessions. The solution mode is newly developed based on the *User-partial* entry of SOLVE, which takes into consideration the deficiency in the precession/nutation models and directly solves the ERP mean within every data piece, rather than by applying constraints on the time rate and the continuation at epoch nodes. Power spectrum analysis of the x component of polar motion is shown by Figure 1, from which the main ocean tidal terms ($Q_1, O_1, P_1, K_1, N_2, M_2, S_2, K_2$) are clearly indicated. As shown in Table 1, least squares estimation of the diurnal and semi-diurnal zonal tide terms within various time spans demonstrates the possible time variation of the amplitude and phase, which may relate to the resonance with the nearby frequency terms and requires further checks in the future.

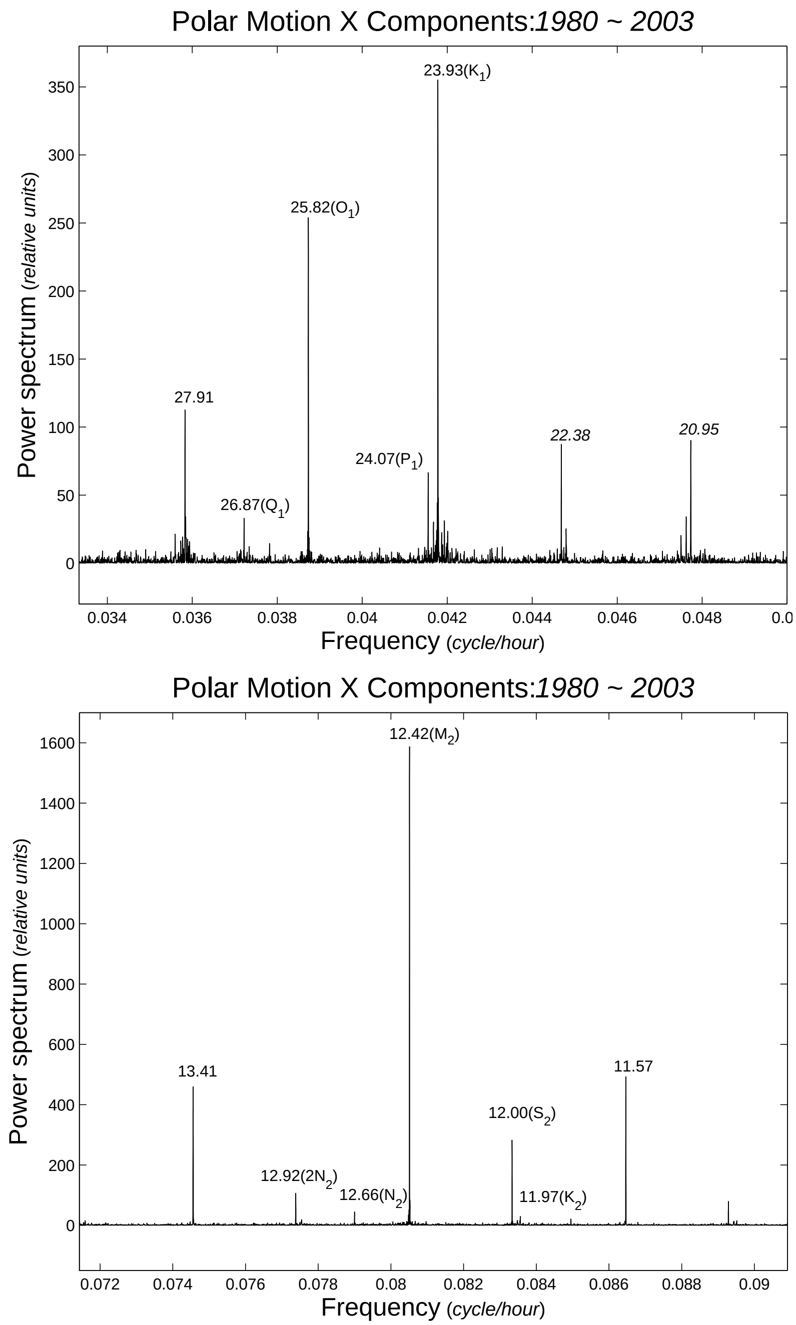

Figure 1. Power spectrum analysis of the x component of polar motion from 1980 to 2003

2.3. Activities Related to Chang'E Project

Our group is closely involved in Chang'E project, the Chinese lunar mission. Our duty is (1) to extract from correlation outputs the VLBI observations delay and delay rate, (2) to study the means of various corrections to satellite VLBI observations and (3) to perform satellite positioning and orbit determination by VLBI observations.

Table 1. Least squares estimation of zonal tide terms within various time spans

Unit: μs

	1990—2003	2000—2003	1996—1999	1990—1995	IERS(2003)
$Q_1 cos$	− 2.20	− 1.17	− 3.45	− 1.95	− 2.50
$Q_1 sin$	3.87	5.75	3.71	3.18	5.12
$O_1 cos$	− 12.13	− 8.97	− 9.93	− 14.56	− 12.07
$O_1 sin$	15.23	19.19	14.52	13.90	16.02
$P_1 cos$	− 3.19	− 3.14	− 3.70	− 2.83	− 3.10
$P_1 sin$	5.45	5.29	4.90	5.89	5.51
$K_1 cos$	8.97	11.88	8.27	8.14	8.55
$K_1 sin$	− 14.80	− 16.78	− 14.37	− 14.05	− 17.62
$N_2 cos$	− 1.54	− 1.76	− 1.76	− 1.36	− 1.56
$N_2 sin$	− 3.19	− 3.48	− 2.86	− 3.27	− 3.79
$M_2 cos$	− 8.74	− 8.85	− 8.64	− 8.73	− 7.15
$M_2 sin$	− 14.80	− 15.38	− 15.18	− 14.37	− 16.19
$S_2 cos$	− 0.18	− 0.72	− 0.32	0.12	− 0.16
$S_2 sin$	− 7.54	− 7.73	− 7.24	− 7.59	− 7.55
$K_2 cos$	0.10	0.56	0.13	− 0.09	0.04
$K_2 sin$	− 2.48	− 2.35	− 2.43	− 2.56	− 2.10

For the observation extraction, a FX type correlator for Chang'E mission is under development at SHAO. It will be capable of processing observations of five stations simultaneously. We are making software to extract the delays and rates from the correlation fringe. The software (i) for single baseline, single channel extraction is completed, (ii) for single baseline, multi-channels it is almost finished except for the check with real observations, (iii) for multi baselines, multi-channels it is still under development.

For the corrections of satellite VLBI observations, we now focus on the ionospheric corrections. In the observation of extragalactic radio sources the technique of dual frequency bands is applied. If the dual bands observation is not always available as in the case of Chang'E mission, it is intended to make the ionospheric correction by using GPS observations. We therefore checked the effectiveness of (i) the application of GPS observations and (ii) the dual bands technique in the satellite observation by VLBI concerning the ionospheric correction.

We compared the ionospheric information from VLBI and GPS for the Seshan25 — Urumqi baseline and for the baselines in CONT02 (October 16-31,2002). As an example, Figure 2 is for Kokee — Westford baseline. In this figure, TEC is the Total Electron Content and TECU is the unit of TEC. "TEC by VLBI" is converted from the ionospheric correction at reference frequency as given in the VLBI database. "TEC by GPS" means the prediction of TEC at the VLBI observation direction based on the reduction of GPS tracking data (The time series of the zenith TEC is deduced from the GPS pseudo-range and carrier phase measurements and then mapped to the direction of the VLBI observation.). "Interval" means the time interval between sessions or the broken time span (not less than three hours) of VLBI tracking, whose epochs are indicated by the black points at the lower part of the figure.

Figure 2 shows that (i) during the VLBI continuous tracking period the correlation between the

VLBI observed TEC and the GPS predicted TEC is very good (more than 80%), which demonstrates the applicability of GPS observations for the ionospheric correction, but (ii) there may exist systematic jumps between the VLBI continuous trackings. In the reduction of astrometric and geodetic VLBI observations the systematic jumps are absorbed into the clock bias leaving no effects on the solutions of source and station coordinates as well Earth Orientation Parameters. In the data reduction of satellite VLBI tracking, practice shows that the clock bias could not be solved simultaneously with the positions or the orbit elements of satellite. In order to determine this systematic jump we therefore need to observe extragalactic radio sources during the satellite tracking, even the dual band technique has already been applied.

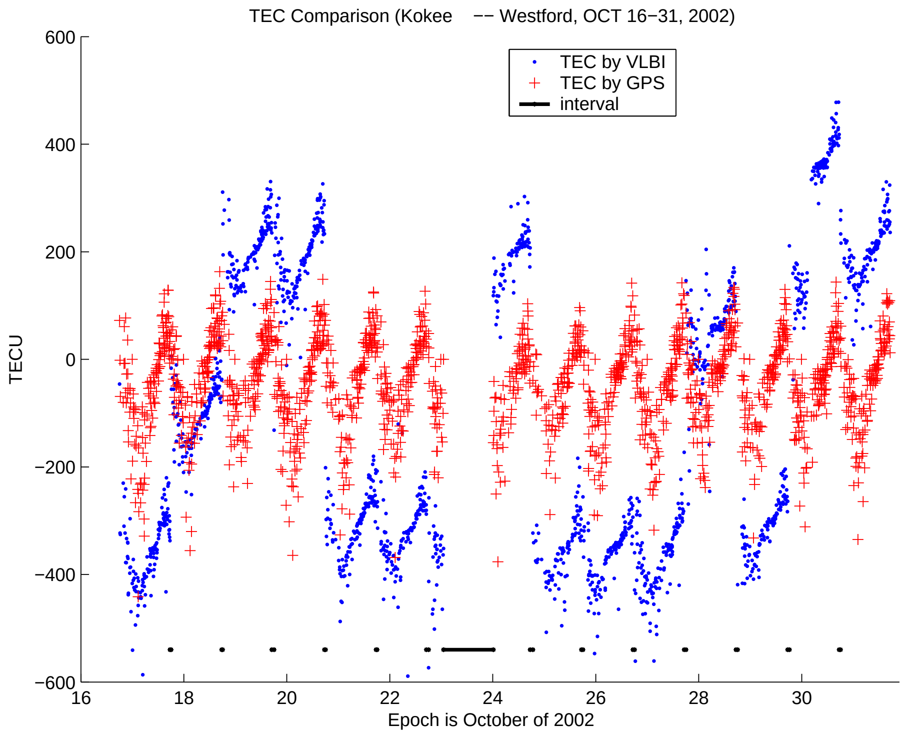

Figure 2. Comparison of TEC observed by VLBI and predicted by GPS

For the satellite positioning and orbit determination by VLBI during the Chang'E mission, the software is still under development and is partly tested against geo-satellite VLBI tracking data. There is still a long way to go to let the software be applicable to the mission.

3. Plans for 2005

We will continue to deliver our efforts on the application studies of VLBI to satellite positioning and orbit determination, mainly concerning the post-correlation stage. We will update our computers in order to be involved in IERS/IVS activities more easily. We will still pay attention to the coordination of VLBI experiments for the APSG program as well as data archives and analysis. We intend to provide to IVS the quarterly solutions of EOP.

U.S. Naval Observatory VLBI Analysis Center

David A. Boboltz, Alan L. Fey, David M. Hall, Kerry A. Kingham

Abstract

This report summarizes the activities of the VLBI Analysis Center at the United States Naval Observatory for calendar year 2004. Over the course of the year, Analysis Center personnel analyzed biweekly diurnal experiments with designations IVS-R1 and IVS-R4 for use in-house and continued timely submission of IVS-R4 databases for distribution to the IVS. During the 2004 calendar year, the USNO Analysis Center produced two periodic global Terrestrial Reference Frame (TRF) solutions with designations usn2004a and usn2004b. Earth orientation parameters based on these solutions, updated by the diurnal (IVS-R1 and IVS-R4) experiments, were submitted to the IVS. New activities in the 2004 calendar year included the generation of daily solution files in the SINEX format based on the 24-hr experiments from January 1996 to present. In addition, analysis center personnel began analyzing intensive experiments for production of an in-house EOP-I series, which should be made available to the IVS in 2005. In regards to the Celestial Reference Frame (CRF), Analysis Center personnel continued a program designed to increase the sky density of ICRF sources especially in the southern hemisphere. Activities included scheduling, analyzing and submitting databases for IVS-CRF experiments and the production of global CRF solutions designated crf2004a and crf2004b. This report also describes activities planned for the 2005 calendar year.

1. Introduction

The USNO VLBI Analysis Center is supported and operated by the United States Naval Observatory (USNO) in Washington, DC. The primary services provided by the Analysis Center are the analysis of diurnal experiments, the production of periodic global Terrestrial Reference Frame (TRF) and Celestial Reference Frame (CRF) solutions, and the submission to the IVS of session-based Earth orientation parameters (EOP-S) based on USNO global TRF solutions. Analysis Center personnel maintain the necessary software required to continue these services to the IVS including periodic updates of the GSFC CALC/SOLVE software package. In addition to operational VLBI analysis, USNO personnel engage in research aimed at developing the next generation ICRF. Information on USNO VLBI analysis activities may be obtained at:

`http://rorf.usno.navy.mil/vlbi/`.

2. Current Analysis Center Activities

2.1. Experiment Analysis and Database Submission

During the 2004 calendar year, personnel at the USNO VLBI Analysis Center continued processing of diurnal (IVS-R1 and IVS-R4) experiments for use in internal USNO global TRF and CRF solutions. USNO is also responsible for the timely analysis of the IVS-R4, and the resulting databases are submitted within 24 hours of correlation for dissemination by the IVS. In addition, Analysis Center personnel continue to be responsible for the analysis and database submission for the periodic IVS-CRF experiments. The primary goal of these experiments is the densification of ICRF sources in the southern hemisphere. In 2004, USNO scheduled and analyzed 15 CRF experiments including IVS-CRF25 through IVS-CRF30, IVS-CRFS1 through IVS-CRFS3, and IVS-CRDS10 through IVS-CRDS15. The analyzed databases were submitted to the IVS. In the

2004 calendar year, Analysis Center personnel also began analyzing IVS intensive experiments for use in an in-house EOP-I time series.

2.2. Global TRF Solutions, EOP and SINEX Submission

USNO VLBI Analysis Center personnel continued to produce periodic global TRF solutions (usn2004a and usn2004b) over the course of the 2004 calendar year. All USNO global TRF solutions including the most recent solution may be found at: `http://rorf.usno.navy.mil/solutions/`.

Session-based Earth orientation parameters derived from these TRF solutions were compared to those derived from GSFC periodic TRF solutions and with the IERS-C04 time series prior to submission to the IVS. Figure 1 shows an example of the comparison information available at the web site mentioned above. In this figure, differences in pole position estimates derived from the

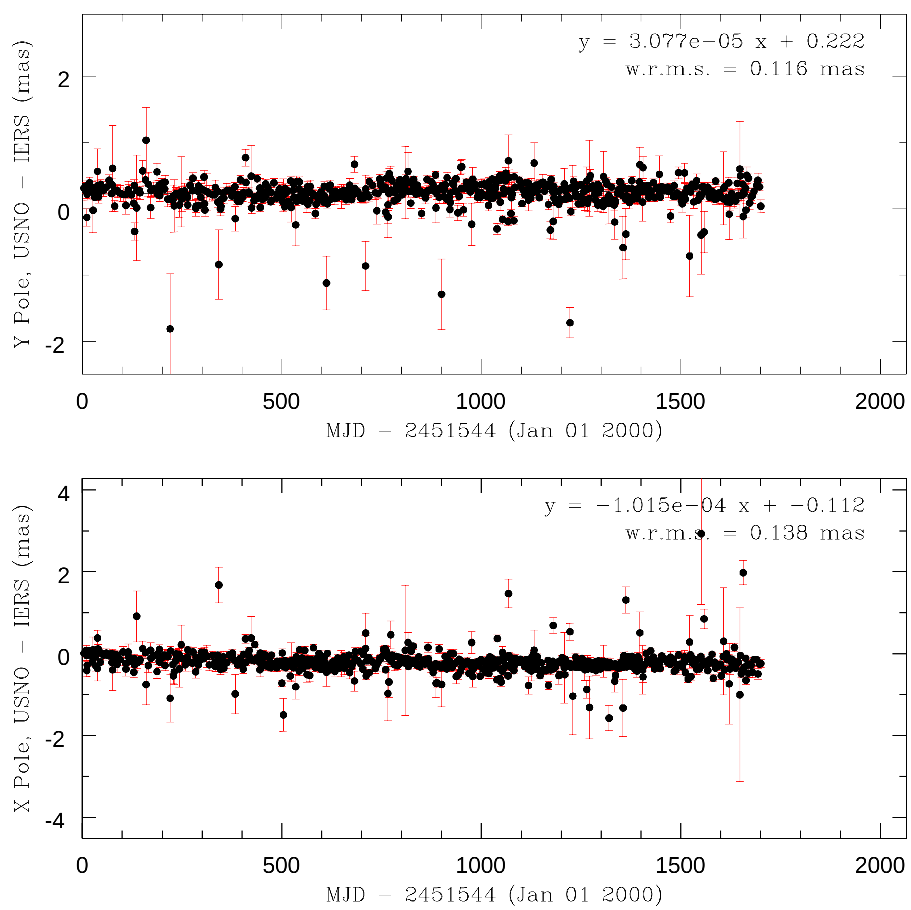

Figure 1. Differences between pole positions estimated from the usn2004b TRF solution and the IERS-C04 time series from January 2000 through August 2004. A weighted least squares linear fit to the data and the weighted RMS are shown in the upper right corner of each plot.

usn2004b solution and the IERS-C04 time series are plotted.

Analysis Center personnel continued to produce an EOP-S series based on the global TRF solutions and continuously updated by new data from the IVS-R1/R4 experiments since the most recent global solution. This updated EOP-S series is submitted to the IVS twice weekly within 24 hours of experiment correlation and is included in the IERS Bulletin A. Analysis Center personnel also worked to produce suitable SINEX format files based on the 24-hr experiments retroactive to January 1996. The SINEX series is continuously updated as new experiments are processed and the resulting files submitted to the IVS.

In addition to EOP-S and SINEX series, USNO Analysis Center personnel began producing an EOP-I series based on the IVS intensive experiments in house. This series is currently being included in the IERS Bulletin A and will likely be made available to the IVS in 2005.

2.3. Celestial Reference Frame

During the 2004 calendar year, Analysis Center personnel continued work on the production of global CRF solutions for dissemination by the IVS including crf2004a and crf2004b. These solutions are routinely compared to the current ICRF and are available through the previously mentioned web site: `http://rorf.usno.navy.mil/solutions/`. As an example, Figure 2 shows the differences between USNO crf2004b source positions and the corresponding ICRF-Ext.2 positions for 717 sources.

During 2004, Analysis Center personnel also continued research into the densification of the

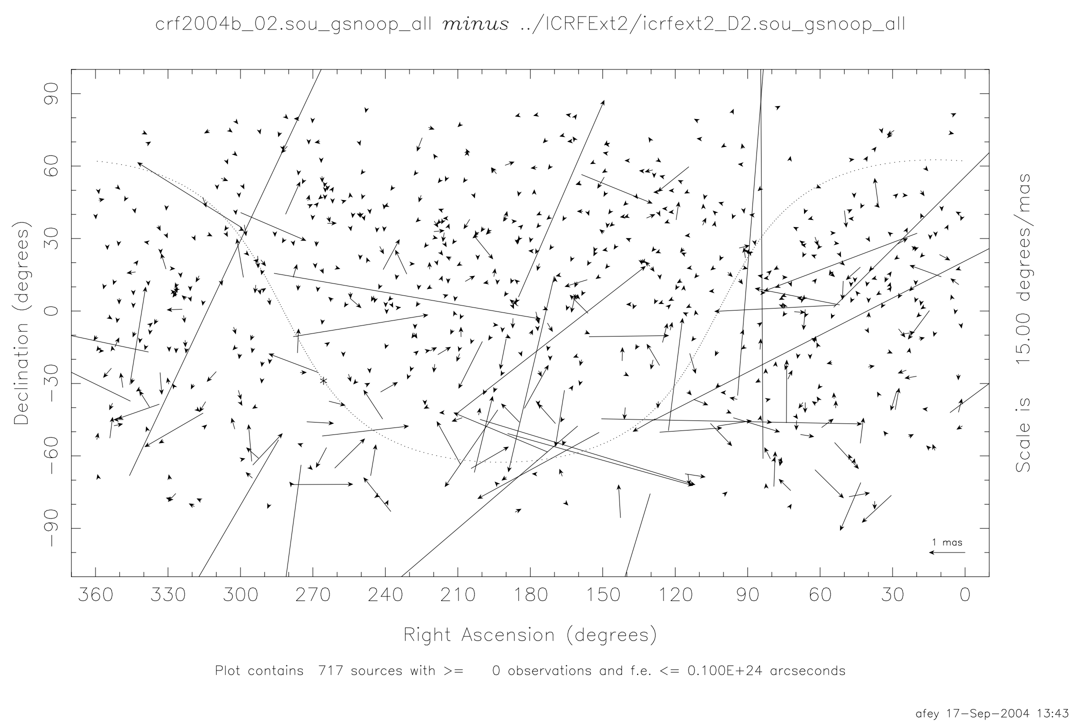

Figure 2. Differences in the source positions as derived from the most recent CRF solution (crf2004b) and ICRF-Ext.2 solution. Plotted are 717 sources in the ICRF. The dotted line represents the galactic equator.

ICRF. Extension 2 of the ICRF was published (Fey et al. 2004, AJ, 127, 3587), which added 109 new sources to the ICRF. All but 4 of these new sources are located at declinations north of $\delta > -30°$. In addition, research designed to increase the sky density of ICRF sources in the southern hemisphere through IVS-CRF and ATNF/USNO observations was continued in 2004. Results from observations recorded between 2002 March and 2004 September are reported in two papers by Fey et al. (2004, AJ, 127, 1791 and 2004, AJ, 128, 2593). Results include astrometric positions for 47 sources with declinations south of $\delta > -30°$.

3. Staff

The staff of the VLBI Analysis Center is drawn from individuals who work at the USNO. The staff and their responsibilities are:

Name	Responsibilities
David A. Boboltz	Periodic global TRF solutions and comparisons, Sinex generation and submission, web page administration, VLBI data analysis.
Alan L. Fey	Periodic global CRF solutions and comparisons, CRF densification research, web page administration, VLBI data analysis.
David M. Hall	VLBI data analysis and database submission, IVS EOP-S submission.
Kerry A. Kingham	Correlator interface, VLBI data analysis

4. Future Activities

For the upcoming year January 2005–December 2005, USNO VLBI Analysis Center personnel plan to accomplish the following activities:

- Continue the processing of biweekly IVS-R1/R4 experiments for use in internal TRF and CRF global solutions and continue submission of IVS-R4 databases for dissemination by the IVS.
- Continue the production of periodic global TRF solutions and the submission of EOP-S estimates to the IVS updated by the IVS-R1/R4 experiments.
- Continue the submission of SINEX format files based on USNO databases for dissemination by the IVS.
- Continue the analysis of intensive experiments and begin submission of EOP-I estimates to the IVS.
- Continue the analysis and database submission for all IVS-CRF experiments.
- Continue ATNF/USNO astrometric observations and research regarding the densification of the ICRF in the southern hemisphere.
- Continue the production of periodic global CRF solutions.

USNO Analysis Center for Source Structure Report

Alan L. Fey, David A. Boboltz, Ralph A. Gaume, Kerry A. Kingham

Abstract

This report summarizes the activities of the United States Naval Observatory Analysis Center for Source Structure for calendar year 2004. VLBA RDV experiment RDV45 was calibrated and imaged. VLBA high frequency (24 & 43 GHz) experiments BL115B and BL115C were calibrated and imaged. A new method for quantifying source structure was developed. Although initially applied to the high frequency data, the method is easily adapted to the study of ICRF sources at the standard frequencies. A Southern Hemisphere imaging and astrometry program for maintenance of the ICRF continued. Imaging of an additional 60 southern hemisphere ICRF sources at 8.4 GHz was completed. Activities planned for the year 2005 include continued imaging of ICRF sources at standard and higher frequencies and continued analysis of source structure and its variation.

1. Analysis Center Operation

The Analysis Center for Source Structure is supported and operated by the United States Naval Observatory (USNO). The charter of the Analysis Center is to provide products directly related to the IVS determination of the "definition and maintenance of the celestial reference frame." These include, primarily, radio frequency images of ICRF sources, intrinsic structure models derived from the radio images, and an assessment of the astrometric quality of the ICRF sources based on their intrinsic structure.

The web server for the Analysis Center is hosted by the USNO and can be accessed by pointing your browser to

`http://rorf.usno.navy.mil/ivs_saac/`

The primary service of the analysis center is the Radio Reference Frame Image Database (RRFID), a web accessible database of radio frequency images of ICRF sources. The RRFID contains 3285 Very Long Baseline Array (VLBA) images of 463 sources at radio frequencies of 2.3 GHz and 8.4 GHz. Additionally, the RRFID contains 783 images of 231 sources at frequencies of 24 GHz and 43 GHz. The RRFID can be accessed from the Analysis Center web page or directly at

`http://www.usno.navy.mil/RRFID/`

A recent addition to the RRFID are Australian Long Baseline Array (LBA) images of 69 southern hemisphere ICRF sources at a radio frequency of 8.4 GHz.

2. Current Activities

2.1. RDV Imaging

VLBA experiment RDV45 (2004JUL14) was calibrated and imaged, adding 160 (80 S-band; 80 X-band) images to the RRFID including images of 11 sources (0316+413, 0426+273, 0602+673, 0620+389, 0656+082, 1030+074, 1226+023, 1240+381, 1417+385, 1738+499, 2235+731) not previously imaged. Unlike previous RDV experiments, the data from the geodetic antennas were flagged before processing leaving only the data obtained by the VLBA. This was done in an attempt to reduce the amount of time required to image these experiments by decreasing the amount of data actually used for imaging. The resultant images are essentially VLBA only but in some instances have lower resolution due to the sub-netting of the array during the RDV observations. A comparison of the angular resolution of the images with previous experiments showed that on average the resolution of the RDV45 images is about a factor of 1.6 times worse than for a full RDV experiment and about a factor of 1.1 times worse than for a VLBA only experiment (i.e. a VLBA experiment with no sub-netting). The consensus opinion reached was that the resulting lower resolution images would hinder structure analysis. Future RDV experiments will be processed with all available data.

2.2. VLBA High Frequency Imaging

VLBA observations to extend the ICRF to K-band (24 GHz) and Q-band (43 GHz) continued in 2004. These observations are part of a joint program between the National Aeronautics and Space Administration, the USNO, the National Radio Astronomy Observatory (NRAO) and Bordeaux Observatory. During the calender year 2004, two VLBA high frequency experiments (BL115B and BL115C) were calibrated and imaged.

2.3. Quantifying Source Structure

The images from the RRFID can be used to classify the sources in terms of their suitability for astrometric use based on their spatial compactness. The CLEAN component model from an image is used to calculate the visibility amplitude, $V(r, \phi)$, in the u,v plane at 24 equally spaced baseline position angles, ϕ, spanning 180° and at 300 equally spaced u,v radii, r, (i.e. baseline lengths) ranging from zero to one Earth diameter.

The visibility amplitude is then averaged over baseline position angle at each u,v radii and then normalized by the zero spacing amplitude. The result is an estimate, $\bar{V}(r)/V(0)$, of the "average" visibility amplitude change as a function of baseline length, r.

The next step is to calculate the standard deviation, $\sigma_V(r)$, over all baseline position angles, ϕ, for each u,v radii and then divide $\sigma_V(r)$ by $\bar{V}(r)$ at each u,v radii. The result is a normalized estimate, $\sigma_V(r)/\bar{V}(r)$, of the azimuthal asymmetry of the source, i.e. if the source is mostly circular, then $\sigma_V(r)/\bar{V}(r)$ at all baseline lengths, r, will be small. If the source is highly elliptical, then $\sigma_V(r)/\bar{V}(r)$ will become increasingly larger with increasing baseline length.

Finally, we calculate an estimate of the radio astrometric quality of the observed sources. For each observed source, a score is tabulated based on the following (higher scores are better):

- **compactness**: range $[0-20]$, *i.e.*, $20 \times [\bar{V}(r_1)/V(0)]$ where r_1 is the u,v radius at which $\bar{V}(r)/V(0)$ reaches a minimum ($r_1 \leq r_x$)
- **asymmetry**: range $[0-40]$, *i.e.*, $40 \times [1 - \sigma_V(r_2)/\bar{V}(r_2)]$ where r_2 is the u,v radius at which $\sigma_V(r)/\bar{V}(r)$ reaches a maximum ($r_2 \leq r_x$)
- **baseline**: range $[0-40]$, *i.e.*, $40 \times [r_x/r_{max}]$ where r_x is the u,v radius at which the normalized "average" visibility and its normalized variation first intersect (eg. see Figure 1c,d) and r_{max} is the maximum u,v radius

The last step is to sum the score for each source. The result is our estimate of radio astrometric

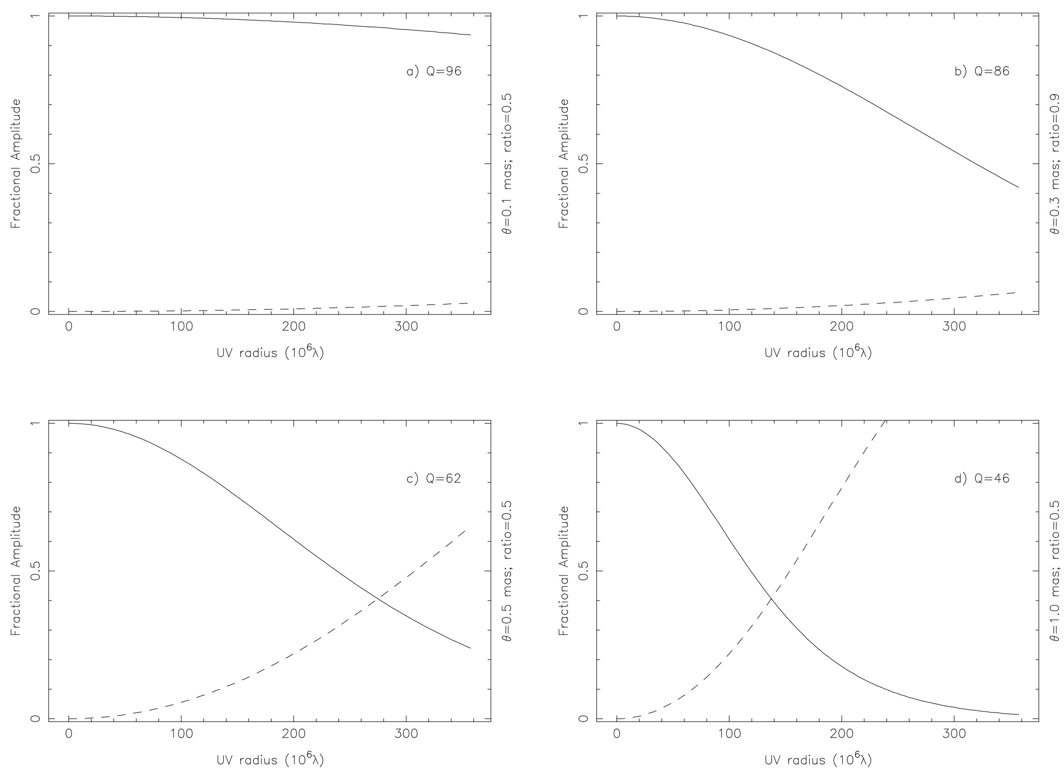

Figure 1. Normalized "average" visibility, $\bar{V}(r)/V(0)$ (solid line), and its normalized variation, $\sigma_V(r)/\bar{V}(r)$ (dashed line), calculated at an observing frequency of 8.4 GHz. Source models are single Gaussian components with a) angular size, $\theta = 0.1$ mas, axial ratio, R=0.5; b) $\theta = 0.3$ mas, R=0.9; c) $\theta = 0.5$ mas, R=0.5; d) $\theta = 1.0$ mas, R=0.5. Q is our estimate of the radio astrometric quality which ranges from zero (for the worst astrometric sources) to one hundred (for the best astrometric sources).

quality, Q, and ranges from zero (for the worst astrometric sources) to one hundred (for the best astrometric sources).

Examples of $\bar{V}(r)/V(0)$ and $\sigma_V(r)/\bar{V}(r)$ calculated at an observing frequency of 8.4 GHz for several simple source models are shown in Figure 1. An example for the source 0138−097 at epoch 2004Feb15 is shown in Figure 2.

Initially applied to the high frequency (K/Q-band) data, the method has not yet been applied to the study of ICRF sources at the standard frequencies.

2.4. ICRF Maintenance in the Southern Hemisphere

The USNO and the Australia Telescope National Facility (ATNF) are collaborating in a continuing VLBI research program in Southern Hemisphere source imaging and astrometry using USNO, ATNF and ATNF-accessible facilities. These observations are aimed specifically toward improvement of the ICRF in the Southern Hemisphere by a) increasing the reference source density with additional S/X-band bandwidth-synthesis astrometric VLBI observations, and b) VLBI imaging at 8.4 GHz of ICRF sources south of $\delta = -20°$.

VLBI images for a total of 69 Southern Hemisphere ICRF sources at a frequency of 8.4 GHz

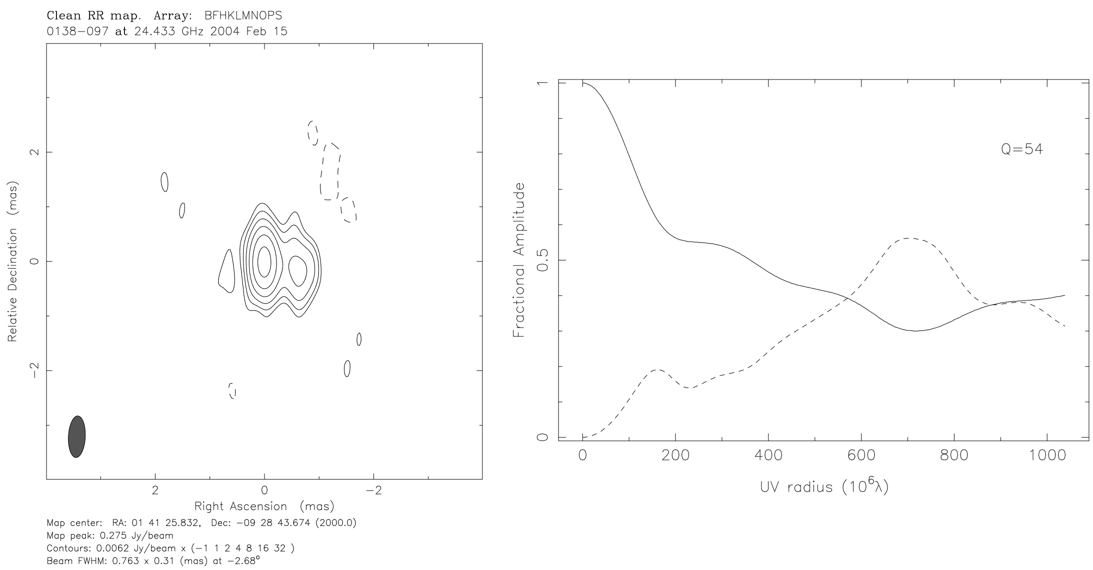

Figure 2. Contour plot of the radio emission at K-band (24 GHz) from the source 0138 − 097 at epoch 2004Feb15; *Right panel*: Normalized "average" visibility, $\bar{V}(r)/V(0)$, (solid line) and its normalized variation, $\sigma_V(r)/\bar{V}(r)$, (dashed line) for the same source.

using the Australian Long Baseline Array were published by Ojha, et al. (2004, AJ, 127, 3609). The images were used to calculate a core fraction, i.e., the ratio of core flux density to total flux density, for all observed sources. The resulting distribution, with a mean value of 0.83, suggests that most sources are relatively compact. However, just over half the observed sources show significant extended emission in the form of multiple compact components. Images for an additional 60 sources have been made and are being prepared for publication.

3. Staff

The staff of the Analysis Center is drawn from individuals who work at the USNO. The staff are: Alan L. Fey, David A. Boboltz, Ralph A. Gaume and Kerry A. Kingham.

4. Future Activities

The Analysis Center currently has a program of active research investigating the effects of intrinsic source structure on astrometric position determination. Results of this program are published in the scientific literature.

The following activities for 2005 are planned:

- Continue imaging and analysis of VLBA 2.3/8.4/24/43 GHz experiments
- Make additional astrometric and imaging observations in the Southern Hemisphere in collaboration with ATNF partners
- Extend structure analysis to 2.3/8.4 GHz experiments

Technology Development Centers

Canadian VLBI Technology Development Center

Anthony Searle, Bill Petrachenko, Mario Bérubé

Abstract

The Canadian Technology Development Center has developed an “end-to-end” geodetic VLBI system built on S2 equipment. The development of this system has led to an operational IVS network. Development work continues to streamline operations and improve S2 instrumentation.

1. Introduction

The Canadian VLBI Technology Development Center is a collaborative effort of the Space Geodynamics Laboratory (SGL), the Geodetic Survey Division of Natural Resources Canada (GSD/NRCan) and the Dominion Radio Astrophysical Observatory (DRAO) of the Herzberg Institute for Astrophysics of the National Research Council of Canada, (DRAO/HIA/NRC).

2. S2 VLBI Geodesy

The S2 VLBI observation program continued in 2004 as the operational “E3” IVS observing network. The “E3” Network consists of Algonquin, Yellowknife, the Canadian Transportable VLBI Antenna (CTVA), Kokee Observatory, Svetloe Observatory, and the Transportable Integrated Geodetic Observatory (TIGO) located in Concepcion, Chile. Initially, the small network size limited the contribution to EOP determination, however the addition of Svetloe Observatory mid–year has improved EOP determination and network robustness.

3. S2 VLBI Data Acquisition System (S2-DAS)

The S2 VLBI data acquisition system is being jointly developed by SGL and GSD. The S2-DAS is designed to accommodate up to four VLBA/Mark IV type single sideband baseband converters (BBCs), each with a local oscillator (LO) independently frequency switchable under computer control. The objective of the development of the S2-DAS is to enable high sensitivity group delay measurements without appealing to a more costly parallel IF/baseband sub-system.

The DAS Operating System (DASOS) has seen extensive development in the past few years. Further software development continues to improve robustness and efficiency. Improved self-testing capabilities and further refinements are currently being tested and will be included in the next official release.

4. S2 VLBI Correlator

The Canadian Correlator is a six station correlator (expandable to ten stations) using S2 playback terminals and is designed to handle S2 frequency–switched bandwidth synthesis data. Recent activity has focussed on the development of visualization and statistical analysis software to enhance system performance monitoring.

The Correlator was developed both for geodetic and astronomy observations, particularly the “Highly Advanced Laboratory for Communications and Astronomy” (HALCA) satellite which was an orbiting VLBI antenna. Correlator staff was cut to one person as a result of the end of HALCA operations. After clearing the backlog of astronomy observations, the correlator was able to clear the backlog of S2-geodetic sessions. The turnaround time for a typical E3 session is now approximately 15 days.

5. Canadian Transportable VLBI Antenna (CTVA)

The CTVA is a 3.6m radio telescope acquired to facilitate densification of the terrestrial reference frame in remote regions. The antenna will be collocated with GPS elements of the Canadian Active Control System (CACS) to provide fiducial station positions. The GSD is responsible for CTVA system development.

The CTVA spent all of 2004 in St. John's, Newfoundland. CTVA uses a group of local university and college students for all observing operations.

The CTVA communication system was upgraded in late 2004. High–speed Internet, web—based cameras, and automated site monitoring will improve site reliability and safety. As the CTVA is now being used in TRF solutions and combinations, accurate eccentricity information was provided to IVS analysts.

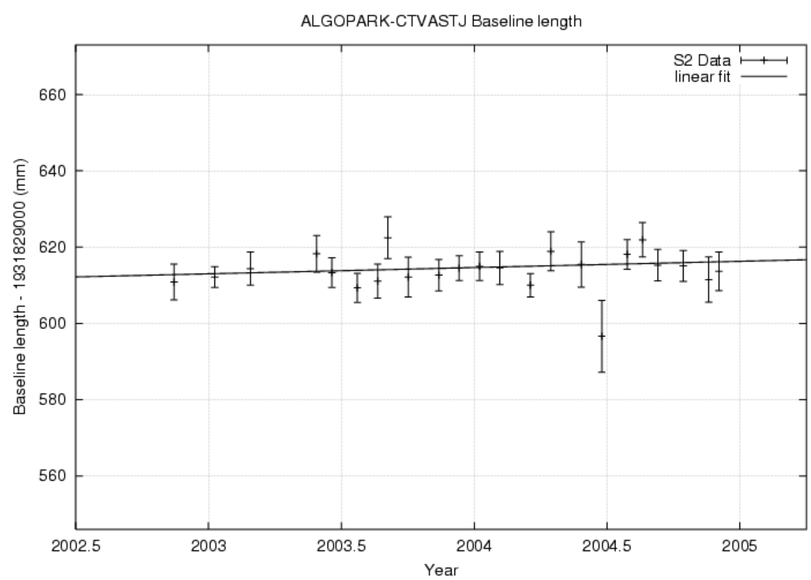

Figure 1. CTVA-ARO Baseline repeatability, wrms 3.5 mm

6. S2 Geodetic Experiment Scheduling, Operations and Analysis

The "E3" network continues to contribute with monthly EOP sessions using 5-6 stations. The EOP results are comparable to R4 sessions but have slightly greater uncertainty due to network configuration and sensitivity. Gilcreek, Alaska will begin to operate in the winter months when Yellowknife Antenna is stowed for winter, keeping the E3 network at 6 stations year–round in 2005.

FFI Technology Development Center - Software Development

Per Helge Andersen

Abstract

FFI's contribution to the IVS as a Technology Development Center will focus primarily on the development and validation of the GEOSAT software for a combined analysis at the observation level of data from VLBI, GPS and SLR. This report shortly summarises the latest improvements of the GEOSAT software. FFI is currently Analysis Center for IVS and ILRS, Technology Development Center for IVS, and Combination Research Center for IERS.

1. The GEOSAT Software

The advantages of the combination of independent and complementary space geodetic data at the observation level is discussed in Andersen ([1]). The models of GEOSAT are listed in Andersen ([2]). The most important changes implemented in 2004 are described in the following.

A new major software component of GEOSAT has been developed for 3D raytracing through the atmosphere. A complete 3D atmospheric model provided daily by ECMWF is input to the software. Based on the available tracking (VLBI, GPS, or SLR) for that specific date a set of tables for each active station is automatically generated with information about the time delay in the different elevation and azimuth directions. Also statistical information concerning the variability of relevant parameters are extracted from the ECMWF data. This information is used in the estimation filter as time-dependent parameter constraints. No mapping functions are used anymore. A new model/parameterization for the atmospheric delay is under extensive testing in GEOSAT. The status is that ten years of VLBI-only sessions have been analyzed. A clear reduction in a posteriori residuals is observed. The Grueger model is default for the MW refractive index and the Ciddor model is default for the optical or near optical wavelengths. The Ciddor model has been tested against Ciddor's own software.

The pressure loading tables provided by Leonid Petrov are used by GEOSAT. For stations not included in this table a simple pressure scaling model is used where the load scale parameter is automatically estimated in the analysis. A grid of reference pressure values has been derived by averaging the surface pressure levels provided by NCEP during the last 20 years.

A model for thermal deformation of the VLBI antenna construction has been included. Thermal coefficients and thermal time delays can be estimated. Empirical VLBI axis offsets distributed by Axel Nothnagel recently, has been implemented in GEOSAT and are used as a priori values for the axis offsets.

Station-dependent center-of-mass corrections for the two Lageos satellites have been implemented according to recommendations of the ILRS signal processing working group. An ocean tide gravity model derived from Topex data has been implemented in GEOSAT.

The station eccentricity file has been checked in great detail and updated with all the most current log files of VLBI, GPS, and SLR. The eccentricity information is treated as a new observation type in GEOSAT in addition to the VLBI, GPS, and SLR observation types.

The GEOSAT software calculates one set of station coordinates and velocities for a reference marker at a colocated station in addition to the eccentricity vector to each different antenna reference point. The software has been extended so that observations from several active VLBI systems, GPS receivers and SLR systems will all contribute to the estimation of the parameters for the station reference marker. The instruments could be operating either simultaneously or in different time windows.

The IERS 2004 Conventions have been fully implemented including the new EOP parameterization. The new subroutines have been extensively tested.

The absolute GPS satellite antenna phase center table published by Rothacher recently has been implemented as an a priori model. The parameters will be estimated during the analysis.

All relevant partial derivatives have been verified against numerical partial derivatives.

In the global processing of several years of data the stable sources listed by Feissel et al. are automatically estimated as constants while the others are estimated as random walk parameters or session parameters. A set of defining stations satisfying certain criteria is automatically estimated as constants where the other stations are estimated as constants during a certain interval (between one day and one month).

The GEOSAT software has been extended for analysis of tracking data from spacecrafts in the Solar systems. Only minor problems remain before the software can be used for such applications.

2. Future Plans

We plan to implement an orbital overlap scheme for automatic evaluation of the orbit quality (GPS, LAGEOS). Observations from the GALILEO navigation system will be applied when available. Only minor changes in GEOSAT are required for this extension.

3. Staff

Dr. Per Helge Andersen - Research Professor of Forsvarets forskningsinstitutt (FFI) and Institute of Theoretical Astrophysics, University of Oslo.

References

[1] Andersen, P. H. Multi-level arc combination with stochastic parameters. Journal of Geodesy (2000) 74: 531-551.

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GSFC Technology Development Center Report

Ed Himwich, John Gipson, Raymond Gonzalez

Abstract

This report summarizes the activities of the GSFC Technology Development Center (TDC) for 2004, and forecasts planned activities for 2005. The GSFC TDC develops station software including the Field System, scheduling software (SKED), hardware including tools for station timing and meteorology, scheduling algorithms, operational procedures, and provides a pool of individuals to assist with station implementation, check-out, upgrades and training.

1. Technology Center Activities

The GSFC IVS Technology Development Center (TDC) develops hardware, software, algorithms and operational procedures. It provides manpower for station visits for training and upgrades. Other technology development areas at GSFC are covered by other IVS components such as the GSFC Analysis Center.

The current staff of the GSFC TDC consists of John Gipson, Ed Himwich and Raymond Gonzalez, employed by NVI, Inc, Chuck Kodak, employed by Honeywell, and William Wildes, employed by NASA/GSFC.

The remainder of this report covers the status of the main areas of development that are currently being pursued.

2. Field System

During this period some new features were released in FS version 9.7:

1. improved support for Mark5A recorders including features for realtime e-VLBI and ftp-VLBI
2. support for the S2 DAS (provided by M. Bérubé, NRCanada)
3. support for NTP for the FS computer time
4. automatic recording of abnormal termination messages to aid debugging of problems encountered in the field
5. conversion of the *fsvue* user interface to a Client-Server model
6. inclusion of support for station specific detectors and stations with no noise diodes in the new *onoff* program
7. addition of numerous small bug fixes and improvements

In the next year, several other improvements are expected, among these are: (1) a complete update to the documentation and in a more modern format that will be easier to use; (2) conversion of the FORTRAN source to use the g77 compiler, this will enable use of the source level debugger, *gdb* for development and field debugging; (3) use of *fsvue* or Real VNC for network operation; (4) *chekr* support for Mark5A systems; (5) use of the Mark IV decoder for phase-cal extraction in the field; and (6) support for periodic firing of the noise diode during observations.

3. DRUDG and SKED

The GSFC TDC is responsible for the development, maintenance, and document of SKED and DRUDG. These two programs are very closely related, and operate as a pair for the preparation of the detailed observing schedule for a VLBI session, and its proper execution in the field. In the normal data flow for geodetic schedules, first SKED is run at the Operation Centers to generate the .skd file that contains the full network observing schedule. Then stations use the .skd file as input to DRUDG for making the control files and procedures for their station. During 2004 many changes were made to both SKED and DRUDG.

3.1. SKED

SKED is the program used to generate geodetic VLBI schedules. Several major enhancements were made to SKED this year.

Astrometric Mode This new mode allows the user to specify a minimum and an optional maximum target for the number of observations for different sources. These numbers are expressed as a percentage of the total number of observations. This option is useful if there are some sources that you want to observe a minimum number of times.

Revamping of Major and Minor Options A major change in sked was to revamp the way that scans are selected, and the subsequent weighting of the scans to determine which scan to use. Major options are associated with which trial scans are generated. Previously some of these options were defined as "parameters", and some were defined as "options". These options were set and listed separately, depending on what they were. Their treatment is now unified. The Minor Options are associated with how a scan is weighted. There are several factors that determine how "desirable" a scan is, among them: length of the scan; number of stations involved; idle time; whether a particular source is involved; whether a particular station is involved; etc. The treatment of the various minor options was unified. The scheduler was also given the ability to weight the options differently. Previously an option was either on or off. You can now weight the different options individually.

Improved Cable Wrap Algorithm The cable wrap algorithm was improved in two respects. First, situations where the antenna moves close to 180 degrees are prohibited. The reason is because sked may choose a different direction than the antenna actually moves. This will lead to cable wrap problems. Second, observations close to a cable wrap boundary are prohibited. The reason is that depending on where the source is when the on-source command is executed, the antenna may choose to go the wrong way to get the correct position, again resulting in cable wrap problems. These changes have resulted in fewer loses due to cable wrap problems.

Source Monitoring Database One of the largest changes made to sked was the ability to query a mysql database which contains information about when sources have been observed, as well as the number of observations scheduled, correlated and observed. This ability is used in the source monitoring program (described under the GSFC Analysis Center Report) to choose sources that have not been observed recently.

3.2. DRUDG

The major changes made to DRUDG this year involved changes and improvements in Mark5A recording. These specifications continued to modify over the year, and DRUDG had to be modified accordingly. Support was added for e-VLBI. Two new SNAP commands were implemented: disk2file, which transfers a scan from the Mark5A rack to another disk, and in2net, which allows the transfer of a scan to a remote location via the internet.

A major enhancement of DRUDG is the ability to handle schedules which are Mark5 aware. Previously a schedule had to be written for tape, and then subsequently changed to use the Mark5A recorder. Currently only SCHED writes Mark5A aware schedules, although it is planned that SKED will be able to generate such schedules by the end of 2005.

3.3. Plans for 2005

The major updated planned for SKED is to make it possible to generate Mark5 schedules directly within SKED. The major update planned for DRUDG is improved S2 support.

Haystack Observatory Technology Development Center

Alan Whitney

Abstract

Work at MIT Haystack Observatory is currently focusing on three areas:

1. Studies for a new geodetic-VLBI system based on small antennas and e-VLBI
2. Development of Mark 5 VLBI data system
3. Development of e-VLBI

We will describe each of these areas.

1. SAGE - Small Advanced Geodetic e-VLBI System Study

At the request of NASA, Haystack Observatory led a study to examine the possibility of replacing the current set of antennas used for geodetic VLBI with small, low-cost, high-efficiency wide-band systems using state-of-the-art technology. The study indicates that such systems are feasible and will be able to yield results which are as good or better than current systems can produce. Two candidate antenna systems were examined, one 6m diameter and one 12m diameter, with attendant first-order estimates for development and deployment costs, as well as a projected development schedule. Copies of the SAGE report are available on request.

2. Mark 5 Development

2.1. Mark 5 Upgrade to SATA Disk Compatibility

Haystack Observatory continues to work with Conduant Corp to develop a Mark 5 upgrade which will allow the Mark 5 to use the new serial-ATA (SATA) disks, as well as the existing parallel-ATA (PATA) disks and disk modules. The upgrade will require the replacement of the current Mark 5 chassis backplane with one which supports both PATA and SATA disk modules. A new disk module and module backplane will be required for SATA disks.

The biggest stumbling block has been finding a connector that is both compatible with SATA requirements (which must support multi-Gbps serial data through the connector – a very tough requirement!) and has sufficient durability for a large number of insertion/removal cycles. The current PATA connector is specified for 5000 insertion/removal cycles, but the best SATA connector is specified for only $\sim$ 500 insertion/removal cycles. The upgraded system will use this connector with the understanding that connector replacement, particularly at the correlators, may be necessary on a scheduled basis. The SATA upgrade is expected to be available mid-2005 and will apply to both Mark 5A and Mark 5B systems.

2.2. Mark 5B VLBI Data System

Development of the Mark 5B VLBI data system is nearing completion at MIT Haystack Observatory. It is based on the same physical platform, uses the same disk-modules as the Mark 5A, and supports the same maximum data rate of 1024 Mbps. However, the Mark 5B will incorporate a VSI standard interface and command set. The Mark 5B system may be used with a Mark IV or VLBA system with the use of simple interface electronics directly from the Mark IV or VLBA samplers, eliminating the need for an external formatter. For existing VLBA systems using VLBA formatters, the current recording limit is 512 Mbps due to formatter limitations; the use of a Mark 5B connected to the sampler outputs will allow the recording of 1024 Mbps. For existing Mark IV systems, the Mark 5B will allow connection of all 14 BBCs to two Mark 5B's for a total aggregate data rate of 1792 Mbps. In addition, the Mark 5B is being designed to support all critical functionality of the Mark IV Station Unit, so that the Mark 5B may be directly connected to a Mark IV correlator through a simple interface without the use of a Mark IV Station Unit. This will allow existing Mark IV correlators to inexpensively expand the number of stations they support. Prototype Mark 5B systems are expected to be available in mid 2005.

3. e-VLBI Development

Haystack Observatory continues to develop the e-VLBI technique with a broad spectrum of efforts, including:

3.1. VSI-E Reference Implementation

David Lapsley has developed a reference implementation of the proposed VSI-E specification. This implementation is intended to act as a demonstration model for VSI-E and is available to all interested parties. The VSI-E framework provides signaling, control, framing and statistics support and is an extension to the Internet standard RFC3550. It also provides flexibility in that it allows users to choose the transport protocol that most suits their networking environment (e.g. UDP, TCP or other variants). Once the reference implementation is fully checked out and any needed changes made, attention can be turned to optimizing the code for high-speed operation.

3.2. Intensive UT1 Transfers from Kokee and Wettzell

After considerable delays in bringing up a satisfactory link to Kokee, success appears now to be in hand. Regular e-VLBI transfers of daily UT1 data from Kokee to ISI-E in Washington, D.C. are expected to begin in February 2005. Wettzell continues to be well connected with an E3 (34 Mbps) link to the University of Regensburg, then on to the German Federal Network (DFN) and the pan-European GEANT research network. Daily UT1 Intensive data will be transferred from Kokee and Wettzell to ISI-E in Washington, D.C.; the data will be hand carried on portable disks from ISI-E to the USNO correlator while USNO awaits a high-speed e-VLBI connection of its own.

3.3. 512 Mbps Real-time e-VLBI Demo at SuperComputing 2004

e-VLBI played a prominent role at this year's Super Computer Conference! This year's meeting, dubbed "SC2004" and held in Pittsburgh 7-12 Nov 2004, hosted live real-time demos for several hours each day during the week long show. E-VLBI shared exhibit space with the DRAGON project, in which MIT Haystack Observatory is a collaborator, and set up an exhibit where live results of real-time e-VLBI from the Haystack correlator were displayed. The demo was done in two modes for several hours during each day of the show:

1. Live real-time data were sent from the Westford (near Haystack in Massachusetts) and

NASA/GSFC (Maryland) antennas at 512 Mbps to the Haystack Mark IV VLBI correlator. The live correlation results were displayed in a 3-dimensional plot (see Figure 1 below) in Pittsburgh as the data were correlated, so the correlation signal could be seen building up and the noise declining as the integration period increased.

2. During periods when the antennas were not available, pre-recorded data were transferred to Haystack from Westford, GGAO, Onsala (Sweden), and Kashima (Japan), followed by immediate correlation, again showing results in Pittsburgh as the correlation proceeded. The transfer rates from all stations were several hundred Mbps.

Many visitors to the booth were interested in seeing a "real" science application of high-speed networking and learning about VLBI and e-VLBI. More information and photos are posted at *http://evlbi.haystack.mit.edu/sc2004.html*.

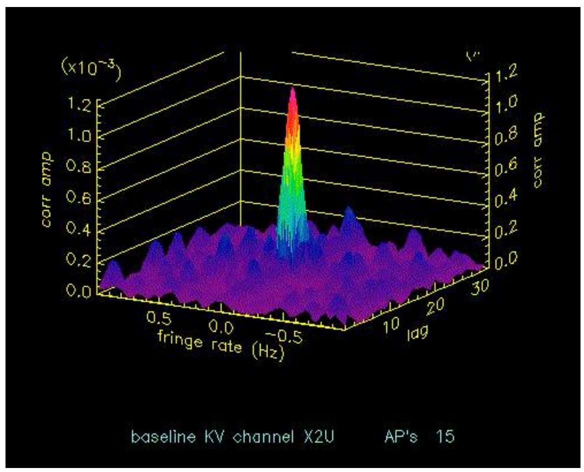

Figure 1. Real-time fringe display at SC2004 from Haystack correlator at SC2004 in Pittsburgh;

3.4. Production e-VLBI Facility Set-up at Haystack

Haystack Observatory has established a "Production e-VLBI Facility" which is dedicated to non-real-time e-VLBI transfers. Typically, about three 24-hr data sets per month from Kashima or Tsukuba are now transferred through this facility, with a typical volume of data around 300 GB/session; we expect usage to ramp up in the near future.

The equipment dedicated to the Production e-VLBI Facility includes:

- Two high speed servers for the transfer and conversion of data
  - Turtle (1.266 GHz Intel Pentium III Dell PowerEdge 2500)
  - Enterprise (a dual 2.4 GHz Xeon Dell PowerEdge 2600)
- Two 1.0 TB Lacie Bigger Extreme Firewire 800 external hard drives for the temporary storage of data
- A Mark 5 for the transfer of data from system disc to Mark 5 disc pack
- 3 Dell PowerConnect 5224 Managed Ethernet Switches

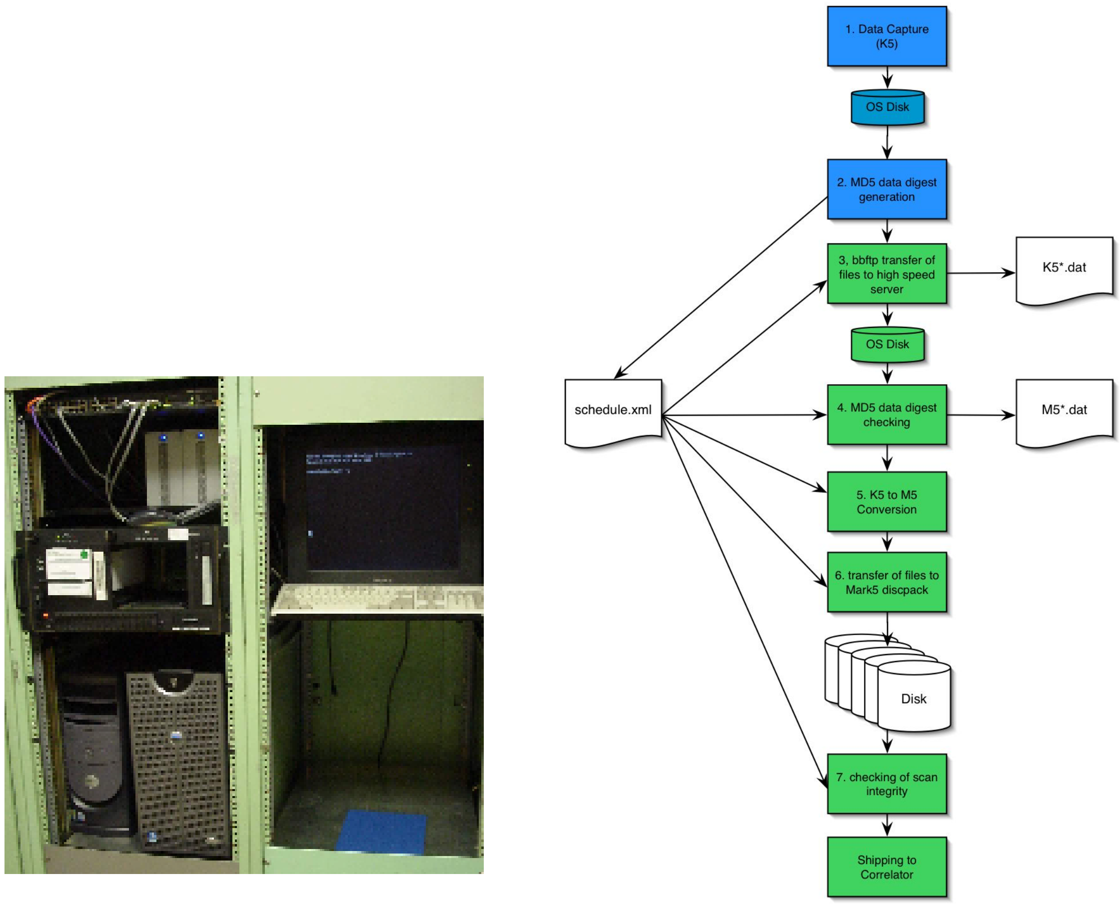

Figure 2. e-VLBI Production Facility (left); K5 to Mark 5A e-VLBI Production Process (right)

After data are collected at Kashima and Tsukuba (both in Japan) on K5 systems, automated procedures are executed to transfer, verify, convert to Mark 5 format, and transfer the data to Mark 5 disk modules. Figure 2 summarizes the steps involved in the process; e-VLBI memo #51, available at *ftp://web.haystack.edu/pub/e-vlbi/memoindex.html*, describes the process and XML control files in detail. The process has been structured in a very modular manner to easily accommodate transfers between both heterogeneous and homogeneous data systems. Currently, the system uses “bbftp” for data transfer, but in the near future this will be converted to VSI-E. .

3.5. DRAGON Project

Researchers at Haystack continue work on the Dynamic Resource Allocation through GMPLS over Optical Networks (DRAGON) program in collaboration with the University of Maryland Mid-Atlantic Crossroads (MAX), Univ. of S. California Information Sciences Institute, George Mason Univ., NASA/GSFC and USNO, and industry partner Movaz Networks. This project has e-VLBI as its premier applications and will provide advanced optical switching infrastructure for supporting e-VLBI experiments.

Institute of Applied Astronomy Technology Development Center

Leonid Fedotov, Alexander Ipatov, Nikolay Koltsov, Vyacheslav Mardyshkin, Andrey Mikhailov

Abstract

The domain of IAA TDC includes the development of software and hardware for Russian VLBI network QUASAR. This report describes IAA activities in this direction.

1. General

Technology Development Center is responsible for all parts of the Russian VLBI network and consists of separate laboratories developing hardware and software for this project. Now the 32 m radio telescope in Svetloe is participating in international VLBI network observations and in domestic radioastronomical and VLBI observations. Radio telescope in Zelenchukskaya is participating in domestic radioastronomical and VLBI observations. At Badary station radio telescope construction work and installation of hardware are finished. The first observations in the single dish mode were carried out.

2. Technical/Scientific

2.1. VLBI Data Acquisition and Recorder Equipment

The VLBI Data Acquisition and Recorder System (Figure 1) was mounted in Svetloe Radio Astronomical Observatory. This system consists of:

- IF switch, developed at IAA,
- Mark IV DAS, including 14 BBCs with up to 16 MHz bandwidth, Mark IV Formatter and Mark IV Decoder,
- Mark 5A recording terminal,
- S2 DAS, including 2 BBCs,
- S2-RT recording terminal,
- Clippers unit, developed at IAA.

The experts of IAA carried out the extensive work on upgrading the DAS to Mark IV level and put into operation the Mark IV Formatter together with the Mark 5A recorder.

Mark IV and Mark 5A are used for observations under the IVS R4, T2 and Euro programs. There is a possibility to make simultaneous records on both Mark 5A and old MarkIII recorder. S2 DAS and S2-RT are used for observations under IVS E3 program. S2-RT is applied for home observations Svetloe-Zelenchukskaya.

In Zelenchukskaya station we have 4-channels DAS, which is developed at IAA, and S2-RT recorder (Figure 2).

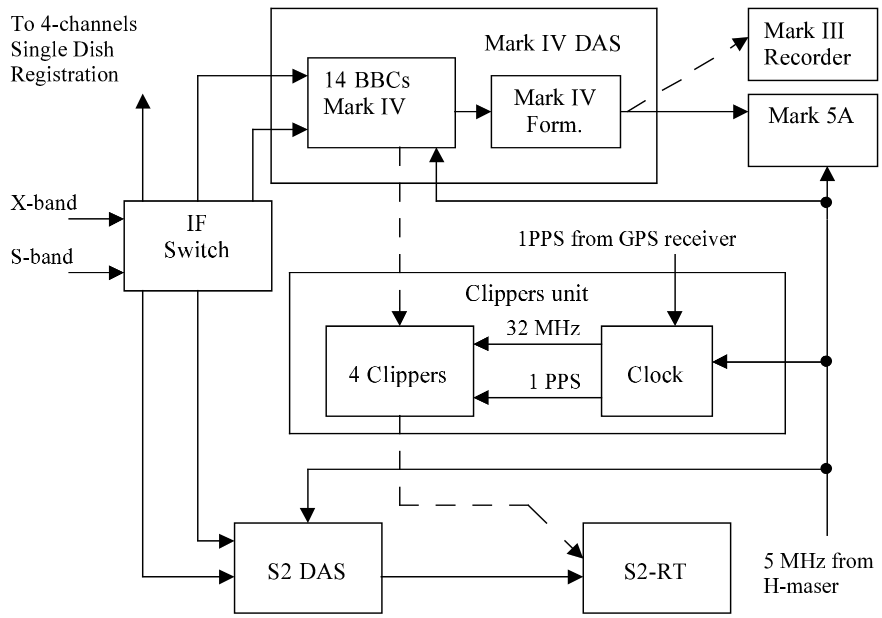

Figure 1. VLBI Data Acquisition and Recorder Equipment in Svetloe observatory

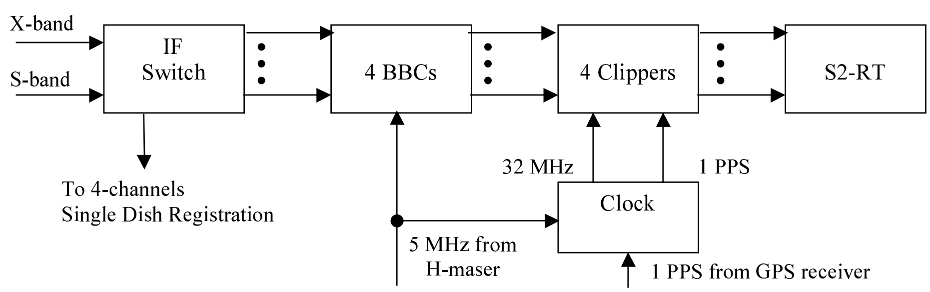

Figure 2. VLBI Data Acquisition and Recorder Equipment in Zelenchukskaya observatory

2.2. The Receivers

In the summer of 2004 in Badary station, west of Baikal lake, (Figure 3) the S/X two channel receivers and the coolers were installed (Figure 4). The results of the first sample observations carried out in December in single dish mode were optimistic.

New low noise front-end amplifiers have been prepared for mounting in Svetloe and Zelenchukskaya station to investigate the possibility of the radio telescope work in the 1.35 cm (22 GHz) waveband. The LNA noise temperature is equal 20 K.

The new control system for receivers has been elaborate. It is connected directly to FS computer. The one channel model was prepared and tested successfully at Svetloe station.

2.3. The Field System Computer

New Field System computers were installed at all three stations. The computers were assembled in Russia, the configuration is based on PentiumIV 2.8 GHz processor with 512 MB RAM and it is analog to the standard FS computer from SWT.

Figure 3. The new radio telescope in Badary

3. Technical Staff

For all the IAA address (8, Zhdanovskaya st., St. Petersburg, 197110, Institute of Applied Astronomy (IAA) RAS, Russia, Director Andrey Finkelstein, FAX +7-812-230-7413) is valid.

4. Outlook

In the new IVS year it is planned:

- to increase the number of clippers in clippers unit up to 14,
- to equip Zelenchukskaya observatory with the 14-channels VLBA4 DAS and Mark 5A recorder equipment,
- to equip Badary observatory with the multichannel DAS, which is developed at IAA, and with the S2-RT recorder,
- to carry out measurements of the radio telescope parameters in the S/X bands in Badary station,
- to rack-mount two new LNAs (1.35 and 13 cm), and to set up the new control receivers system in Svetloe station,
- to rack-mount three new LNAs (two for 1.35 and one for 3.5 cm) in Zelenchukskaya station,
- to carry out measurements of the radio telescope parameters in the S/X bands in Badary station.

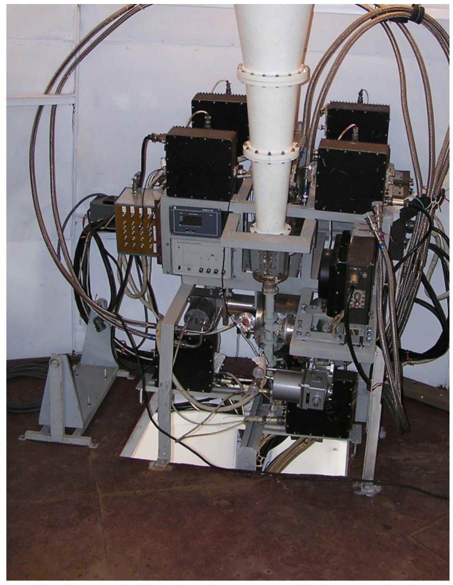

Figure 4. The S/X two channel receivers (left) and the coolers (right) installed at Badary radio telescope

Table 1. Technical Staff

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Technology Development Center at NICT

Tetsuro Kondo, Yasuhiro Koyama, Hiroshi Takeuchi

Abstract

National Institute of Information and Communications Technology (NICT) (former Communications Research Laboratory (CRL)) has led the development of VLBI technique in Japan and has been keeping high activities in both observations and technical developments. This report gives a review of the Technology Development Center (TDC) at NICT and summarizes recent activities.

1. TDC at NICT

National Institute of Information and Communications Technology (NICT) (former Communications Research Laboratory (CRL))[1] has published the newsletter "IVS NICT-TDC News (former IVS CRL-TDC News)" twice a year in order to inform about developments in VLBI related technology in Japan as an IVS technology development center to the world. The newsletter is available through the Internet at the following URL

http://www2.nict.go.jp/ka/radioastro/tdc/index.html.

2. Staff Members of NICT TDC

Table 1 lists the staff members at NICT who are involved in the VLBI technology development center at NICT.

Table 1. Staff Members of NICT TDC as of December, 2004 (alphabetical).

Name	Works
Ichikawa, Ryuichi	Delta VLBI
Kawai, Eiji	Antenna system
Kimura, Moritaka	e-VLBI
Kondo, Tetsuro	e-VLBI
Koyama, Yasuhiro	e-VLBI
Kuboki, Hiromitsu	Antenna system
Nakajima, Junichi	Giga-bit system
Sekido, Mamoru	Delta VLBI
Takeuchi, Hiroshi	e-VLBI

[1]Under the "Reorganization and Rationalization Plan of Special Public Institutions" adopted at a Japanese Cabinet meeting held in December 2001, CRL and the Telecommunications Advancement Organization of JAPAN (TAO) were reorganized as the National Institute of Information and Communications Technology (NICT) on April 1, 2004.

3. Recent Activities

3.1. K5 Software Development

The processing speed of K5 software correlator has continued to increase with the improvement in PC performance as well as the use of a better algorithm. Throughputs of the K5 software correlator for a geodetic use are shown in Figure 1 for various kinds of CPUs and clock frequencies, such as Pentium III, Pentium 4, AMD, Celeron, etc. Data used for this measurement are 4ch 1bit-8MHz sampling (=32 Mbps) data, and 32-lag complex correlation function is computed. At present time, the throughput of about 17 Mbps is achieved for an AMD Athlon64 3200+ CPU in case of computing 32-lag correlation, which corresponds to 34 Mbps for 16-lag correlation considering a linear relation between the number of lags and the throughput. The throughput in the case of using a Pentium4 2.5GHz CPU is about 12 Mbps for 32-lag correlation and 24 Mbps for 16-lag correlation. It is clear from the figure that the processing speed increases with the clock frequency, so that we can expect a faster throughput in the future if the progress in CPU performance continues [4].

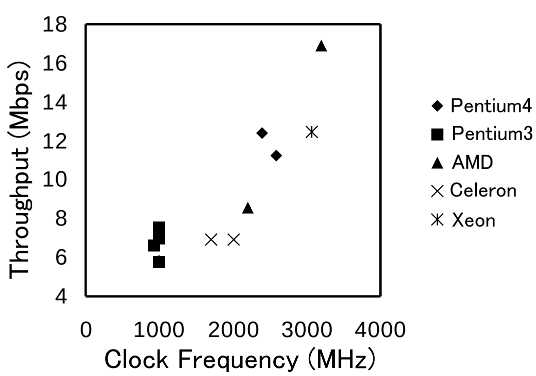

Figure 1. Throughputs of K5 software correlator for a geodetic purpose for various kinds of CPUs and clock frequencies. Throughputs for computing 32-lag correlation function is plotted.

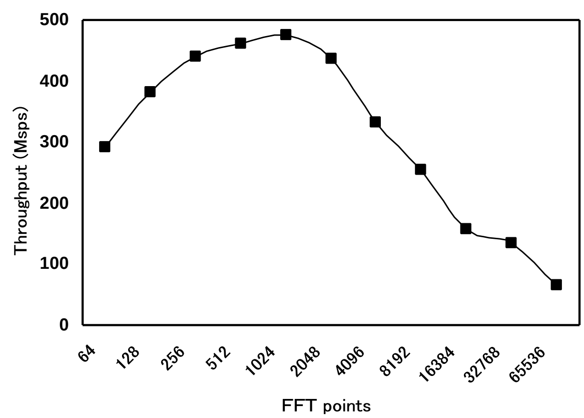

Figure 2. Throughputs of FX-type software correlator for astronomical purposes running on an Xserve G5 equipped with dual 2GHz G5 processors. Throughputs are measured for different numbers of FFT points.

We have also developed an FX-type software correlator, which is specialized for processing speed to process gigabit VLBI system data, mostly for astronomical use [1], [2]. In order to bring out the maximum performance, various kinds of optimizations, such as an effective use of multi-processors and utilization of SIMD (Single Instruction Multiple Data) technology for parallel processing, are applied into the software. An assembler language program is also used partially to improve the performance. Figure 2 shows results of a benchmark test of the software correlator that runs on an Xserve G5 equipped with dual 2GHz G5 processors. Throughput is measured for a number of different FFT points. It reaches up to about 500 Msps (sample per second) at 1024 FFT points, which corresponds to the processing speed of 1 Gbps for 2 bit sampling data. The size of cache memory of CPU affected the performance at large number of lags, results in the performance loss.

In addition, efforts have been made to realize distributed processing by using multiple CPUs. One of the efforts is to utilize unused CPU power of the conventional PCs by developing a screen saver program to download the data files from a server and perform the software correlation [6]. We named this system VLBI@home which consists of a server PC and client PCs. The screen saver program runs on the client PCs. The server program run on the server PC processes the requests from the clients. Currently, the screen saver program has been developed on the Microsoft Windows operating systems. Any PCs connected to the Internet can be used as the clients. Once the screen saver program is installed, the program begins to communicate with the server program over the Internet and begin to download the data files and then perform the correlation processing. After the processing completes, the results will be reported to the server program and then the client system begins to process the next data set. If the user of the PC system starts to use the CPU for the other purposes, the screen saver program promptly terminates the processing but the processing can be resumed later when the CPU is not used for a certain time specified by the screen saver configuration.

3.2. US-Japan e-VLBI for a Rapid UT1 Measurement [3]

On June 29, 2004, one hour e-VLBI session between Westford and Kashima stations was performed to obtain UT1 estimation as soon as possible. The observed data were transferred and processed promptly after the observing session, rapid turnaround UT1 estimation was demonstrated as fast as about 4.5 hours after the session.

The session was performed for about one hour. After the session, data observed at Westford with the Mark-5 were transferred to Kashima through Abilene/TransPAC/JGNII networks. The data of 13.5 GBytes were transferred in about 1 hour and 15 minutes and the average data transfer rate was 24 Mbps. The transferred data were then converted to the K5 file format. During the one hour session, 18 scans were recorded in total. Thirteen scans were assigned to the NFS based distributed software correlation using 12 CPUs running on Linux and FreeBSD. The remaining 5 scans were assigned to VLBI@home and 9 CPUs were used. As soon as the data format conversion completed, the software correlation was started. Although this software correlation processing has a potential to process all scan data within 30 minutes, it took about 2 hours and 38 minutes due to the problem of local area network (LAN) at Kashima. Immediately after all the correlation processing completed, database files were generated and the data analysis was performed by using CALC and SOLVE softwares developed by the Goddard Space Flight Center of NASA. The data analysis was completed at about 4 hours and 30 minutes after the last observation in the session was completed. If the LAN problem does not occur, it will be possible to estimate UT1-UTC from the similar test session within 3 hours after the observing session.

3.3. Delta e-VLBI for Spacecraft Positioning [5]

Technology development of e-VLBI for spacecraft positioning was continued using the "HAYABUSA" that is a Japanese spacecraft launched in May, 2003 aiming at the sample return from the asteroid. Delta VLBI observations were carried out on October 16–18, 2004. The tool to utilize closure phase relation for connecting phase delay from a scan to the next scan has been developed.

3.4. Software Baseband Converter [7]

We have been developing a software-based baseband conveter (BBC) which down-converts intermediate frequency (IF) signals to baseband using data aquired by our PC-based gigabit data acquisition system K5/PC-VSI. IF-signals are sampled by an ADS-1000 with the rate of 1Gbps or 512Mbps. The data are filtered by band-pass filtering software and are converted to base-band signals, of which bandwidth is selectable from 512kHz to 32MHz. Quantization bits can be set to 1,2,4, and 8, and one or two baseband channels can be extracted in real-time with a PC.

Acknowledgements. The research and development of e-VLBI in Japan have been promoted by a close collaboration of NICT, Geographical Survey Institute, NTT Laboratories, National Astronomical Observatory, Japan Aerospace Exploration Agency, Gifu University and Yamaguchi University. The US-Japan e-VLBI was conducted in collaboration with MIT Haystack Observatory team. We would like to acknowledge the continuing effort of all staff members of Haystack Observatory to lead an experiment to a success. We also wish to thank all staff members of the NTT Communications Corporation, KDDI R&D Laboratories, NTT Laboratories, JGNII, and Internet2 involving in the international e-VLBI experiment for their efforts to establish the necessary network connection.

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The IVS Technology Development Center at the Onsala Space Observatory

Tobias Nilsson, Gunnar Elgered

Abstract

The main development activity in 2004 was to investigate the stability of the Astrid Water Vapor Radiometer (WVR) at the Onsala Space Observatory in terms of its instrumental noise. We have investigated algorithms based on a model for the correlations between slant wet delays in different directions. Using these algorithms it is possible to estimate how much of the variability in the measured slant wet delays was due to the atmospheric variability and how much was due to instrumental noise.

1. Introduction

The Astrid WVR has been operating at the Onsala Space Observatory since 1980. Since 1993 it has been running almost continuously, observing the sky through sequential azimuth and elevation scans. From the WVR measurements it is possible to infer the slant wet delay of radio signals in the atmosphere.

A new control and data acquisition system was installed in the Astrid WVR during the end of 2002 and the beginning of 2003 [1]. Results from an investigation on the stability of the WVR before and after the upgrade were presented in our Technology Development Center Report of 2003 [2]. This investigation assessed the stability of the WVR by calculating the Allan variances for data taken in the zenith direction. Only measurements in the same direction (in our case zenith) could be used since the horizontal variations of the atmospheric water vapor are too large. Here we present the results from another investigation on the WVR stability, in which we use a theory of atmospheric turbulence to describe the variability of water vapor. This makes it possible to use all of the data from the normal WVR data acquisition, i.e. continuous scanning on the sky.

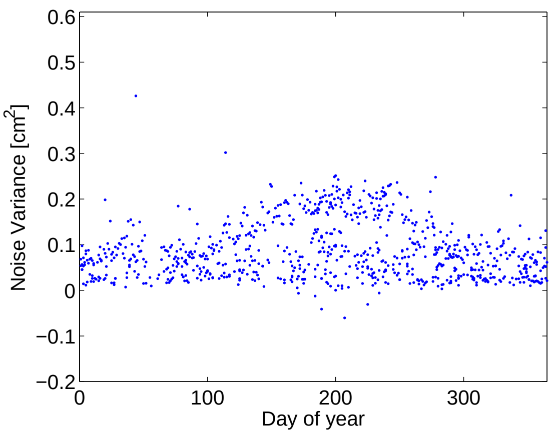
2. Results

In order to use ordinary WVR observations to characterize the stability of the WVR we need to know how much of the observed variability in the slant wet delays comes from the variability of the atmosphere and how much from the WVR instrumental noise, respectively. For our application it is reasonable to assume that the temporal variations can be neglected for short time intervals (less than 5 minutes). The contribution from spatial variations in the atmospheric water vapor can be described using the theory of atmospheric turbulence [3].

The model used to describe the spatial variability of the water vapor [3] gives the correlations between the slant wet delays in two different directions. We have adopted a model for the variance of the WVR noise as a function of elevation angle for the observed slant delays mapped to the zenith direction:

$$Var[N] = \frac{A}{m(\epsilon)} \tag{1}$$

Here $Var[N]$ is the variance of the noise, A is the variance of the noise in the zenith direction, and $m(\epsilon)$ is the mapping function at the elevation angle ϵ [4]. We have shown that the expectation value squared difference between the measured zenith mapped slant wet delay in two different



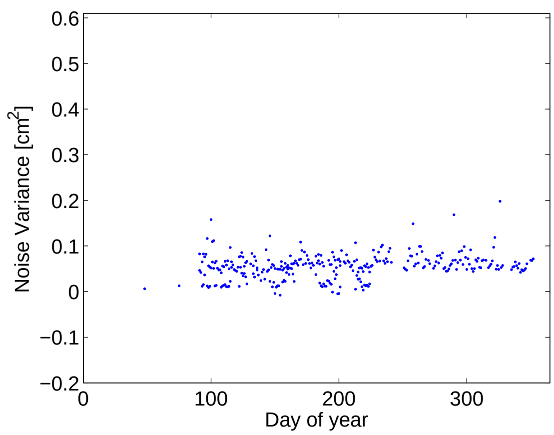


Figure 1. Results of the variance of the radiometer noise for the periods 1992–2002 (left) and 2003–2004 (right). Each point represents one single day. The negative noise variances retrieved for some days indicate that for these days the atmospheric turbulence model did not describe the WVR observations well.

directions can be expressed as the model prediction for the difference plus the sum of the variances of the noise [5]:

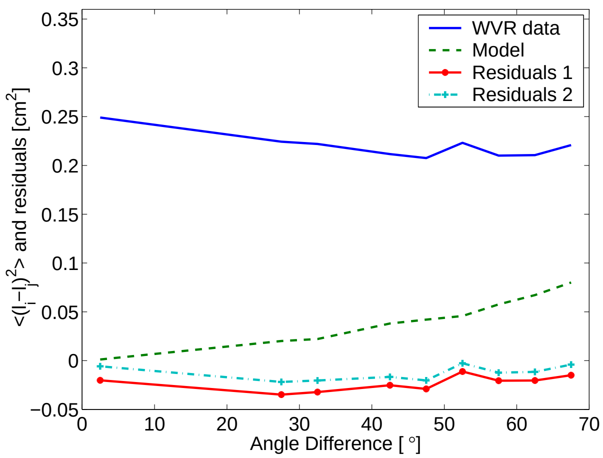
$$\left\langle (\hat{l}_i - \hat{l}_j)^2 \right\rangle = k^2 \left\langle (l_i - l_j)^2 \right\rangle + \left(m(\epsilon_i)^{-2} + m(\epsilon_j)^{-2} \right) \cdot A \tag{2}$$

Here $\hat{l}_i$ and $\hat{l}_j$ are the measured equivalent zenith wet delays in the two directions i and j, $\langle (l_i - l_j)^2 \rangle$ the model prediction for the difference between the two equivalent zenith wet delays, and k^2 a constant describing the magnitude of the atmospheric turbulence [5]. We can then assess the measurement noise of a WVR by making a least-squares fit to the WVR data to (2) in order to estimate k^2 and the WVR noise variance.

Figure 1 shows the variance of the noise retrieved as a function of the day of the year. Shown are results from before (1992–2002) and after (2003–2004) the upgrade. As seen the variance of the noise is on the average lower and more stable for the period after the upgrade of the WVR. Before the upgrade the average variance is 0.087 cm^2 and after the upgrade it is 0.055 cm^2. For the time after the upgrade there are almost no data from the January–March period. This is because the upgrade was not completed until the end of March 2003, and during the beginning of 2004 the radiometer was being repaired.

Before the upgrade the WVR sometimes produced measurements which were clearly incorrect (outliers). These were most likely caused by a failing A/D converter. We made an investigation designed to determine if these incorrect observations were still present after the upgrade. These observations explain why some of the retrieved noise variances in Figure 1 are negative (which is obviously an incorrect result due to a non valid model). If we remove all obvious outliers from the WVR data (observations of equivalent zenith wet delay having a large deviation from neighboring observations), the effect of the remaining incorrect observations can approximately be accounted for by including an additional, elevation-angle independent noise term in the least-squares fit:

$$\left\langle (\hat{l}_i - \hat{l}_j)^2 \right\rangle = k^2 \left\langle (l_i - l_j)^2 \right\rangle + \left(m(\epsilon_i)^{-2} + m(\epsilon_j)^{-2} \right) \cdot A + B \tag{3}$$



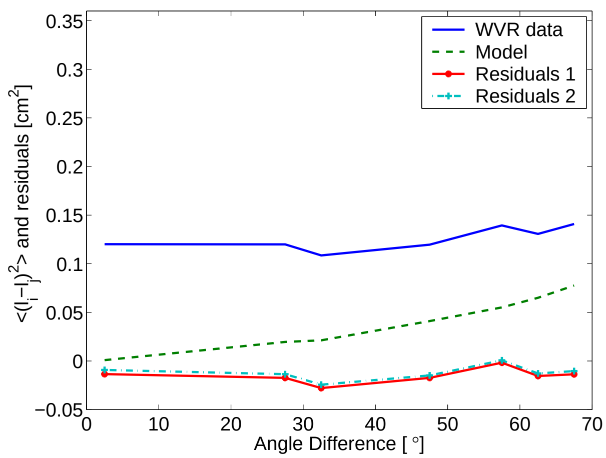


Figure 2. Comparison of the results using the two different models (Equations (2) and (3)). Shown are results from May 11–15 2002 (left) and May 11–15 2004 (right). The measured and predicted variations in equivalent zenith wet delay and the residuals for the two different models for the WVR noise are displayed as function of difference in elevation angle. Residual 1 is the residual using (2) and residual 2 is for (3).

Here B is the variance of the additional noise.

The results clearly show that an improved agreement between the model and the WVR data when the model for the outlier observations is included in the analysis of the data for the period before the upgrade. For the period after the upgrade the improvement is not that obvious. This is displayed in Figure 2 using the results from five days in May 2002 and five days in May 2004. Displayed are the measured differences in equivalent zenith wet delay, the model prediction for this difference (without any noise), and the residuals when not including (residual 1) and including (residual 2) the model for the outlier observations, plotted as a function of their difference in elevation angle. Due to difficulty in displaying all data in a clear way (the difference will depend on the angle between the two observation directions and the two elevation angles) only data where one of the directions is in the zenith are shown. The improvement when considering the incorrect observations is more obvious for the 2002 period, i.e. before the upgrade. Hence we can conclude that the number of outlier observations has been reduced by the upgrade of the WVR data acquisition system.

3. Future plans

We propose that the model developed can be used as a tool to continuously monitor the variability of the atmosphere and the stability of the WVR using observations spread over the sky. As the instrument will continue to acquire more data the impact of the upgrade will also become more evident. We have not yet been able to make an investigation on the impact of the upgrade for a whole year, including all seasons, since we are lacking data for the the period January–March.

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IVS Information

IVS Terms of Reference

1. Summary

1.1. Charter

The International VLBI Service for Geodesy and Astrometry (IVS) is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. IVS provides a service which supports geodetic and astrometric work on reference systems, Earth science research, and operational activities.

IVS is an official Service of the International Association of Geodesy (IAG).

1.2. Objectives

IVS fulfills its charter through the following objectives. The primary objective of IVS is to foster VLBI programs as a joint service. This is accomplished through close coordination to provide high-quality VLBI data and products.

The second objective of IVS is to promote research and development activities in all aspects of the geodetic and astrometric VLBI technique. This objective also supports the integration of new components into IVS. The further education and training of VLBI participants is supported through workshops, reports, electronic network connections, and other means.

The third objective of IVS is to interact with the community of users of VLBI products and to integrate VLBI into a global Earth observing system. IVS interacts closely with the International Earth Rotation Service (IERS) which is tasked by the IAU and IUGG with maintaining the international celestial and terrestrial reference frames and with monitoring Earth rotation.

To meet these objectives, IVS coordinates VLBI observing programs, sets performance standards for VLBI stations, establishes conventions for VLBI data formats and data products, issues recommendations for VLBI data analysis software, sets standards for VLBI analysis documentation, and institutes appropriate VLBI product delivery methods to ensure suitable product quality and timeliness. IVS closely coordinates its activities with the astronomical community because of the dual use of many VLBI facilities and technologies for both astronomy and astrometry/geodesy.

IVS accepts observing proposals for research and operational programs that conform to the IVS objectives.

1.3. Data Products

VLBI data products contribute uniquely to these important determinations:

- definition and maintenance of the celestial reference frame
- monitoring universal time (UT1) and length of day (LOD)
- monitoring the coordinates of the celestial pole (nutation and precession)

These results are the foundation of many scientific and practical applications requiring the use of an accurate inertial reference frame, such as high-precision navigation and positioning. IVS provides, through the collaborative efforts of its components, a variety of significant VLBI data products with differing applications, timeliness, detail, and temporal resolution, such as:

- all components of Earth orientation parameters at regular intervals
- terrestrial reference frame
- VLBI data in appropriate formats
- VLBI results in appropriate formats
- local site ties to reference points
- high-accuracy station timing data
- surface meteorology, tropospheric and ionospheric measurements

All VLBI data products are archived in IVS Data Centers and are publicly available.

1.4. Research

The VLBI data products are used for research in many related areas of geodesy, geophysics, and astrometry, such as:

- UT1 and polar motion excitation (over periods of hours to decades)
- solid Earth interior research (mantle rheology, anelasticity, libration, core modes, nutation/precession)
- characterization of celestial reference frame sources and improvements to the frame
- tidal variations (solid Earth, oceanic, and atmospheric)
- improvements in the terrestrial reference frame, especially in the vertical (scale) component
- climate studies

To support these activities, there are ongoing research efforts whose purpose is to improve and extend the VLBI technique in such areas as:

- improvements in data acquisition and correlation
- refined data analysis techniques
- spacecraft tracking (Earth-orbiting and interplanetary)
- combination of VLBI data and results with other techniques

2. Permanent Components

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic, astrometric, and other results, and archives and publicizes data products. IVS accomplishes its goals through the types of permanent components described in this section. IVS will accept proposals at any time for a permanent component. Such proposals will be reviewed by the Directing Board. The seven types of IVS permanent components are:

- Network Stations
- Operation Centers
- Correlators

- Analysis Centers
- Data Centers
- Technology Development Centers
- Coordinating Center

IVS acquires VLBI data, correlates the data, analyzes the data to produce geodetic and astrometric results, and archives and publicizes data products. IVS accomplishes its goals through the operational components described below.

2.1. Network Stations

The IVS observing network consists of high performance VLBI stations.

- Stations can be dedicated to geodesy or have multiple uses (including astronomical observations or satellite tracking applications).
- Stations comply with performance standards for data quality and operational reliability set up by the Directing Board.
- VLBI data acquisition sessions are conducted by groups of Network Stations that are distributed either globally or over a geographical region.

2.2. Operation Centers

The IVS Operation Centers coordinate the routine operations of one or more networks. Operation Center activities include:

- planning network observing programs,
- establishing operating plans and procedures for the stations in the network,
- supporting the network stations in improving their performance,
- making correlator time available at an IVS Correlator,
- generating the detailed observing schedules for use in data acquisition sessions by IVS Network Stations,
- posting the observing schedule to an IVS Data Center for distribution and to the Coordinating Center for archiving.

IVS Operation Centers follow guidelines from the Coordinating Center for timeliness and schedule file formats. Operation Centers cooperate with the Coordinating Center in order to define:

- the annual master observing schedule,
- the use of antenna time,
- tape availability and shipping,
- the use of other community resources.

2.3. Correlators

The IVS Correlators process raw VLBI data and station log files following a data acquisition session. Their other tasks are to:

- provide immediate feedback to the Network Stations about problems that are apparent in the data,
- jointly maintain the geodetic/astrometric community's tape pool,
- make processed data available to the Analysis Centers,
- regularly compare processing techniques, models, and outputs to ensure that data from different Correlators are identical.

2.4. Analysis Centers

The IVS coordinates VLBI data analysis to provide high-quality products for its users. The analyses are performed by Analysis Centers and by Associate Analysis Centers.

Analysis Centers are committed to produce series of Earth Orientation Parameters (EOP) or series of individual EOP components, without interruption and at a specified time lag to meet IVS requirements. In addition, Analysis Centers produce station coordinates and source positions in regular intervals.

The Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Analysis Center makes from IVS recommendations are properly documented. Analysis Centers provide timely feedback about station performance. In addition to these regular services, Analysis Centers may also perform any task of an Associate Analysis Center.

Associate Analysis Centers are committed to regularly submit specialized products using complete series or subsets of VLBI observing sessions. The analysis is performed for specific purposes as recognized by the Directing Board such as exploitation of VLBI data for new types of results, investigations of regional phenomena, reference frame maintenance, or special determinations of Earth orientation parameters. The Associate Analysis Centers place their final results in IVS Data Centers for dissemination to researchers and other users. They adhere to IVS recommendations for the creation of high-quality products and their timely archiving and distribution. Any deviations that an Associate Analysis Center makes from IVS recommendations are properly documented.

2.5. Data Centers

The IVS Data Centers are repositories for VLBI observing schedules, station log files, and data products. Data Centers may mirror other Data Centers to make the distribution and maintenance of data more efficient and reliable.

- Data Centers are the primary means of distributing VLBI products to users.
- Data Centers work closely with the Coordinating Center and with the Analysis Centers to ensure that all the information and data required by IVS components are quickly and reliably available.

Data Centers provide the following functions:

- receive and archive schedule files from Operation Centers,
- receive and archive log files and ancillary data files from the Network Stations,
- receive and archive data products from the Analysis Centers,
- provide access and public availability to IVS data products for all users.

2.6. Technology Development Centers

The IVS Technology Development Centers contribute to the development of new VLBI technology. They may be engaged in hardware and/or software technology development, or evolve new approaches that will improve the VLBI technique and enhance compatibility with different data acquisition terminals. They will:

- design new hardware,
- investigate new equipment,
- develop new software for operations, processing or analysis,
- generate new information systems,
- develop, test, and document prototypes of new equipment or software,
- assist with deployment, installation, and training for any new approved technology.
- After dissemination of the new hardware or software, the centers may continue to provide maintenance and updating functions.

2.7. Coordinating Center

The IVS Coordinating Center is responsible for coordination of both the day-to-day and the long-term activities of IVS, consistent with the directives and policies established by the Directing Board. Specifically, the Coordinating Center monitors, coordinates, and supports the activities of the Network Stations, Operation Centers, Correlators, Data Centers, Analysis Centers, and Technology Development Centers. The Coordinating Center works closely with the Technology Coordinator, the Network Coordinator, and the Analysis Coordinator to coordinate all IVS activities.

The primary functions of the Coordinating Center are to:

- coordinate observing programs approved by the Directing Board,
- maintain the master schedule of observing sessions, coordinating the schedule with astronomical observing programs and with IVS networks,
- foster communications among all components of the IVS,
- define the best use of community resources,
- develop standards for IVS components,
- provide training in VLBI techniques,
- organize workshops and meetings, including an annual IVS technical meeting,
- produce and publish reports of activities of IVS components,

- maintain the IVS information system and archive all documents, standards, specifications, manuals, reports, and publications,
- provide liaison with the IERS, IAG, IAU, and other organizations,
- provide the Secretariat of the Directing Board.

3. Coordinators

Specific IVS activities for technology, network data quality, and data products are accomplished through the functions performed by three coordinators: a Network Coordinator, an Analysis Coordinator, and a Technology Coordinator.

3.1. Network Coordinator

The IVS Network Coordinator is selected by the Directing Board from responses to an open solicitation to all IVS components. The Network Coordinator represents the IVS Networks on the Directing Board and works closely with the Coordinating Center. The Network Coordinator is responsible for stimulating the maintenance of a high quality level in the station operation and data delivery. The Network Coordinator performs the following functions:

- monitors adherence to standards in the network operation,
- participates in the quality control of the data acquisition performance of the network stations,
- tracks data quality and data flow problems and suggests actions to improve the level of performance,

The Network Coordinator works closely with the geodetic and astronomical communities who are using the same network stations for observations. The Coordinator takes a leading role in ensuring the visibility and representation of the Networks.

3.2. Analysis Coordinator

The IVS Analysis Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Analysis Centers. The Analysis Coordinator is responsible for coordinating the analysis activities of IVS and for stimulating VLBI product development and delivery. The Analysis Coordinator performs the following functions:

- fosters comparisons of results from different VLBI analysis software packages and different analysis strategies,
- encourages analysis software documentation,
- participates in comparisons of results from different space geodetic techniques,
- monitors Analysis Centers' products for high quality results and for adherence to IVS standards and IERS Conventions,
- ensures that analysis products from all Analysis Centers are archived and available for the scientific community, and
- forms the official products of IVS, as decided by the IVS Directing Board, using a suitable combination of the analysis results submitted by the Analysis Centers.

The Analysis Coordinator works closely with the geodetic and astronomical communities who are using some of the same analysis methods and software. The Analysis Coordinator plays a leadership role in the development of methods for distribution of VLBI products so that the products reach the widest possible base of users in a timely manner. The coordinator promotes the use of VLBI products to the broader scientific community and interacts with the IVS Coordinating Center and with the IERS.

3.3. Technology Coordinator

The IVS Technology Coordinator is selected by the Directing Board from responses to an open solicitation to the IVS Technology Development Centers. The Technology Coordinator is responsible for coordinating the new technology activities of IVS and for stimulating advancement of the VLBI technique. The Technology Coordinator performs the following functions:

- maintains cognizance of all current VLBI technologies and ongoing development
- coordinates development of new technology among various IVS components
- helps promulgate new technologies to the geodetic/astrometric community
- strives to ensure the highest degree of global compatibility of VLBI data acquisition systems

The Technology Coordinator works closely with the astronomical community because of the many parallels between the technology development required for both groups.

4. Directing Board

4.1. Roles and Responsibilities

The Directing Board determines policies, adopts standards, and approves the scientific and operational goals for IVS. The Directing Board exercises general oversight of the activities of IVS including modifications to the organization that are deemed appropriate and necessary to maintain efficiency and reliability.

A specific function of the Board is to set scientific goals for the IVS observing program. The Board will establish procedures for external research programs and will review any proposals thus received.

The Board may determine appropriate actions to ensure the quality of the IVS products and that the IVS components maintain the adopted standards.

4.2. Membership

The Directing Board consists of appointed members who serve ex officio, members elected by the Directing Board, and members elected by the IVS components. The members are:

Appointed members ex officio:

- IAG representative
- IAU representative
- IERS representative
- Coordinating Center Director

Through a reciprocity agreement between IVS and IERS the IVS serves as the VLBI Technique Center for IERS, and as such its designated representative(s) serve on the IERS Directing Board. In turn, the IERS Directing Board designates a representative to the IVS Directing Board. This arrangement is to assure full cooperation between the two services.

Selected by Directing Board upon review of proposals from IVS Member Organizations:

- Technology, Network, and Analysis Coordinators (3 total)

Elected by Directing Board upon recommendation from the Coordinating Center (see below):

- Members at large (3)

Elected by IVS Components (see below):

- Correlators and Operation Centers representative (1)
- Analysis and Data Centers representative (1)
- Networks representatives (2)
- Technology Development Centers representative (1)

Total number: 15

The four appointed members are considered ex officio and are not subject to institutional restrictions.

The five members of the Directing Board who are elected by IVS Permanent Components must each be a member of a different IVS Member Organization. All elected members serve staggered four-year terms once renewable.

At large members are intended to ensure representation on the Directing Board of each of the components of IVS and to balance representation from as many countries and institutions and IVS interests as possible. At large members serve 2-year terms once renewable.

A Board member who departs before the end of his/her term is replaced by a person selected by the Directing Board. The new member will serve for the remainder of the original term.

The three Coordinators are selected by the Directing Board on the basis of proposals from IVS Member Organizations. On a two-thirds vote the Directing Board may call for new proposals for any Coordinator when it determines that a new Coordinator is required. Coordinators are encouraged to give at least three months notice before resigning.

4.3. Elections

Election of Board members by the IVS components shall be conducted by a committee of three Directing Board members, the chair of which is appointed by the chair of the Directing Board. The committee solicits nominations for each representative from the relevant IVS components. For each position, the candidate who receives the largest number of votes from the Associate Members will be elected. In case of a tie the Directing Board will make the decision.

4.4. Chair

The chair is one of the Directing Board members and is elected by the Board for a term of four years with the possibility of reelection for one additional term. The chair is the official representative of IVS to external organizations.

4.5. Decisions

Most decisions by the Board are made by consensus or by simple majority vote of the members present. In case of a tie, the chair shall vote but otherwise does not vote. If a two-thirds quorum is not present, the vote shall be held later by electronic mail. A two-thirds vote of all Board members is required to modify the Terms of Reference, to change the chair, or to change any of the members elected by the Directing Board before the normal term expires.

4.6. Meetings

The Board meets at least annually, or more frequently if meetings are called by the chair or at the request of at least three Board members. The Board will conduct periodic reviews of the IVS organization and its mandate, functions, and components. The reviews should be done every four years.

5. Definitions

5.1. Member Organizations

Organizations that support one or more IVS components are IVS Member Organizations. Individuals associated with IVS Member Organizations may become IVS Associate Members.

5.2. Affiliated Organizations

Organizations that cooperate with IVS on issues of common interest, but do not support an IVS component, are IVS Affiliated Organizations. Affiliated Organizations express an interest in establishing and maintaining a strong working association with IVS to mutual benefit. Individuals affiliated with IVS Affiliated Organizations may become IVS Correspondents.

5.3. Associate Members

Individuals associated with organizations that support an IVS component may become IVS Associate Members. Associate Members are generally invited to attend non-executive sessions of the Directing Board meetings with voice but without vote. Associate Members take part in the election of the incoming members of the Directing Board representing the IVS components.

5.4. Corresponding Members

IVS Corresponding Members are individuals on a mailing list maintained by the Coordinating Center. They do not actively participate in IVS but express interest in receiving IVS publications, wish to participate in workshops or scientific meetings organized by IVS, or generally are interested in IVS activities. Ex officio corresponding members are the following:

- IAG General Secretary
- President of IAG Section II – Advanced Space Technology
- President of IAG Section V – Geodynamics
- President of IAU Division I – Fundamental Astronomy

- President of IAU Commission 19 – Rotation of the Earth
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Geodetic Institute of the University of Bonn	Germany
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National Institute of Polar Research	Japan
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IVS Permanent Components

(listed by types, within types alphabetical by component name)

Network Stations

Component Name	Sponsoring Organization	Country
Algonquin Radio Observatory	Geodetic Survey Division, Natural Resources Canada	Canada
Fortaleza, Radio Observatório Espacial do Nordes (ROEN)	Centro de Rádio Astronomia e Aplicações Espaciais	Brazil
Gilmore Creek Geophysical Observatory	NASA Goddard Space Flight Center	USA
Goddard Geophysical and Astronomical Observatory	NASA Goddard Space Flight Center	USA
Hartebeesthoek Radio Astronomy Observatory	Foundation for Research and Development	South Africa
Hobart, Mt. Pleasant Radio Observatory	University of Tasmania	Australia
Kashima 34m	National Institute of Information and Communications Technology (NICT)	Japan
Key Stone Project Koganei 11m	National Institute of Information and Communications Technology (NICT)	Japan
Key Stone Project Kashima 11m	National Institute of Information and Communications Technology (NICT)	Japan
Kokee Park Geophysical Observatory	National Earth Orientation Service (NEOS)	USA
Matera	Agenzia Spaziale Italiana (ASI)	Italy
Medicina	Istituto di Radioastronomia C.N.R.	Italy
Mizusawa 10m	National Astronomical Observatory of Japan (NAOJ)	Japan
Noto (Sicily)	Istituto di Radioastronomia C.N.R.	Italy
Ny-Ålesund Geodetic Observatory	Norwegian Mapping Authority	Norway
ERS/VLBI Station O'Higgins	Bundesamt für Kartographie und Geodäsie (BKG)	Germany
Onsala Space Observatory	Chalmers University of Technology	Sweden
Seshan	Joint Laboratory for Radio Astronomy (JLRA), CAS and Shanghai Observatory, CAS	China
Simeiz	Laboratory of Radioastronomy of Crimean Astrophysical Observatory	Ukraine
Svetloe Radio Astronomy Observatory	Institute of Applied Astronomy RAS	Russia
JARE Syowa Station	National Institute of Polar Research	Japan

Transportable Integrated Geodetic Observatory (TIGO)	Universidad de Concepción (UdeC), Universidad del Bío Bío (UBB), Universidad Católica de la Santísima Concepción (UCSC), Instituto Geográfico Militar (IGM), Bundesamt für Kartographie und Geodäsie (BKG)	Chile, Germany
Tsukuba VLBI Station	Geographical Survey Institute	Japan
Nanshan VLBI Station	Chinese Academy of Sciences	China
Westford Antenna, Haystack Observatory	NASA Goddard Space Flight Center	USA
Fundamentalstation Wettzell	Bundesamt für Kartographie und Geodäsie (BKG) and Forschungseinrichtung Satellitengeodäsie der Technischen Universität München (FESG)	Germany
Observatório Astronómico Nacional - Yebes	Instituto Geográfico Nacional	Spain
Yellowknife Geophysical Observatory	Geodetic Survey Division, Natural Resources Canada	Canada

Operation Centers

Component Name	**Sponsoring Organization**	**Country**
Geodetic Institute Bonn (GIUB)	University of Bonn	Germany
CORE Operation Center	NASA Goddard Space Flight Center	USA
NEOS Operation Center	National Earth Orientation Service (NEOS)	USA

Correlators

Component Name	**Sponsoring Organization**	**Country**
Astro/Geo Correlator at MPI	Bundesamt für Kartographie und Geodäsie and Geodätisches Institut der Universität Bonn	Germany
MIT Haystack Correlator	NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Correlator	Institute of Applied Astronomy	Russia
National Institute of Information and Communications Technology (NICT)	National Institute of Information and Communications Technology (NICT)	Japan
Tsukuba VLBI Center	Geographical Survey Institute	Japan
Washington Correlator	National Earth Orientation Service (NEOS)	USA

Data Centers

Component Name	Sponsoring Organization	Country
BKG, Leipzig	Bundesamt für Kartographie und Geodäsie	Germany
Crustal Dynamics Data Information System (CDDIS)	NASA Goddard Space Flight Center	USA
GeoDAF	Agenzia Spaziale Italiana (ASI)	Italy
Italy CNR	Istituto di Radioastronomia CNR	Italy
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Observatoire de Paris	Observatoire de Paris	France

Analysis Centers

Component Name	Sponsoring Organization	Country
Astronomical Institute of St.-Petersburg University	Astronomical Institute of St.-Petersburg University	Russia
Geoscience Australia	Geoscience Australia	Australia
Observatoire de Bordeaux	Observatoire de Bordeaux	France
Centro di Geodesia Spaziale (CGS)	Agenzia Spaziale Italiana	Italy
DGFI	Deutsches Geodätisches Forschungsinstitut	Germany
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
GIUB-BKG Analysis Center	Geodätisches Institut der Universität Bonn and Bundesamt für Kartographie und Geodäsie	Germany
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Analysis Center	Institute of Applied Astronomy	Russia
Italy CNR	Istituto di Radioastronomia CNR	Italy
Institute of Geodesy and Geophysics (IGG)	Institute of Geodesy and Geophysics (IGG), of the University of Technology, Vienna	Austria
Jet Propulsion Laboratory	Jet Propulsion Laboratory	USA
Main Astronomical Observatory	Main Astronomical Observatory, National Academy of Sciences, Kiev	Ukraine
National Astronomical Observatory of Japan	National Astronomical Observatory of Japan	Japan

National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Observatoire de Paris	Observatoire de Paris	France
Onsala Space Observatory	Chalmers University of Technology	Sweden
Shanghai Observatory	Shanghai Observatory, Chinese Academy of Sciences	China
U. S. Naval Observatory Analysis Center	U. S. Naval Observatory	USA
U. S. Naval Observatory Analysis Center for Source Structure	U. S. Naval Observatory	USA

Technology Development Centers

Component Name	**Sponsoring Organization**	**Country**
Canadian VLBI Technology Development Center	CRESTech, NRCan, DRAO, CSA	Canada
Forsvarets forskningsinstitutt (FFI)	Norwegian Defence Research Establishment	Norway
Goddard Space Flight Center	NASA Goddard Space Flight Center	USA
Haystack Observatory	Haystack Observatory and NASA Goddard Space Flight Center	USA
Institute of Applied Astronomy Technology Development Center	Institute of Applied Astronomy	Russia
National Institute of Information and Communications Technology	National Institute of Information and Communications Technology	Japan
Onsala Space Observatory	Chalmers University of Technology	Sweden

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List of Acronyms

ACU	Antenna Control Unit
AGU	American Geophysical Union
AIPS	Astronomical Image Processing System
ANU	Australian National University (Australia)
APPS	Advanced Precise Positioning System
APSG	Asia-Pacific Space Geodynamics program
APT	Asia Pacific Telescope
ARIES	Astronomical Radio Interferometric Earth Surveying program
ARO	Algonquin Radio Observatory (Canada)
ASI	Agenzia Spaziale Italiana (Italian Space Agency) (Italy)
ATA	Allen Telescope Array
ATM	Asynchronous Transfer Mode
ATNF	Australia Telescope National Facility (Australia)
AUSLIG	AUstralian Surveying and Land Information Group (now GA) (Australia)
A-WVR	Advanced Water Vapor Radiometer
BBC	Base-Band Converter
BIPM	Bureau Internacional de Poids et Mesures (France)
BKG	Bundesamt für Kartographie und Geodäsie (Germany)
CACS	Canadian Active Control System
CAS	Chinese Academy of Sciences (P.R. China)
CAY	Centro Astronómico de Yebes (Spain)
CC	(IVS) Coordinating Center
CDDIS	Crustal Dynamics Data Information System (USA)
CDP	Crustal Dynamics Project
CGS	Centro di Geodesia Spaziale (Italy)
CMVA	Coordinated Millimeter VLBI Array
CNES	Centre National d'Etudes Spatiales (France)
CNRS	National Center for Scientific Research (France)
CNS	Communication, Navigation and Surveillance systems, Inc.
CORE	Continuous Observations of the Rotation of the Earth
CPP	IERS Combination Pilot Project
CRAAE	Center for Radio Astronomy and Space Applications (Brazil)
CRAAM	Centro de Rádio-Astronomia e Astrofísica Mackenzie
CRESTech	Centre for Research in Earth and Space Technology (Canada)
CRF	Celestial Reference Frame
CRL	Communications Research Laboratory (now NICT) (Japan)
CRS	Celestial Reference System
CSA	Canadian Space Agency (Canada)
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
CTVA	Canadian Transportable VLBI Antenna
CUTE	CRL and University Telescopes Experiment (Japan)
DAR	Data Acquisition Rack

DAS	Data Acquisition System
DASOS	DAS Operating System
DAT	Digital Audio Tape
DBBC	Digital Baseband Converter
DeltaDOR	Delta Differenced One-way Range
DGFI	Deutsches Geodätisches ForschungsInstitut (Germany)
DLR	German Aerospace Center
DOMES	Directory Of MERIT Sites
DORIS	Doppler Orbitography by Radiopositioning Integrated on Satellite
DRAGON	Dynamic Resource Allocation through GMPLS over Optical Networks
DRAO	Dominion Radio Astrophysical Observatory (Canada)
DSN	Deep Space Network
DSS	Deep Space Station
DVLBI	Differential VLBI
ECMWF	European Center for Medium Range Weather Forecasting
ENSG	L'École Nationale des Sciences Géographiques
ENVISAT	ENVIronmental SATellite
EOP	Earth Orientation Parameters
ERP	Earth Rotation Parameters
e-VLBI	Electronic VLBI
EVN	European VLBI Network
FCN	Free Core Nutation
FESG	Forschungseinrichtung Satellitengeodäsie/Technical University of Munich (Germany)
FFI	Forsvarets ForskningsInstitutt (Norwegian Defence Research Establishment) (Norway)
FFT	Fast Fourier Transform
FGS	Forschungsgruppe Satellitengeodäsie (Germany)
FS	Field System
FTP	File Transfer Protocol
FWF	Austrian Science Fund
GAPE	Great Alaska and Pacific Experiment
GARNET	GSI Advanced Radiotelescope NETwork (Japan)
GARR	Gruppo per l'Armonizzazione delle Reti della Ricerca (Italy)
GARS	German Antarctic Receiving Station (Antarctica)
GBT	Green Bank Telescope (USA)
GeoDAF	Geodetical Data Archive Facility (Italy)
GFZ	GeoForschungsZentrum (Germany)
GIUB	Geodetic Institute of the University of Bonn (Germany)
GLONASS	GLObal NAvigation Satellite System
GLORIA	GLObal Radio Interferometry Analysis
GMST	Greenwich Mean Sideral Time
GPS	Global Positioning System
GSD	Geodetic Survey Division of Natural Resources Canada (Canada)
GSFC	Goddard Space Flight Center (USA)

GSI	Geographical Survey Institute (Japan)
HPBW	Half Power Beam Width
HTSI	Honeywell Technology Solutions Incorporated (USA)
IAA	Institute of Applied Astronomy (Russia)
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICRF	International Celestial Reference Frame
ICRS	International Celestial Reference System
IERS	International Earth Rotation Service
IGFN	Italian Space Agency GPS Fiducial Network (Italy)
IGG	Institute of Geodesy and Geophysics (Austria)
IGM	Instituto Geográfico Militar (Chile)
IGN	Instituto Geográfico Nacional (Spain)
IGS	International GPS Service
ILRS	International Laser Ranging Service
IMF	Isobaric Mapping Function
INAF	Istituto Nazionale di Astrofisica (Italy)
INPE	Instituto Nacional de Pesquisas Espaciais (Brazil)
IPWV	Integrated Precipitable Water Vapor
IRA	Istituto di RadioAstronomia (Italy)
IRIS	International Radio Interferometric Surveying
ISAS	Institute of Space and Astronautical Science (Japan)
ITRF	International Terrestrial Reference Frame
ITSS	(Raytheon) Information Technology and Science Services (USA)
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service for Geodesy and Astrometry
JADE	JApanese Dynamic Earth observation by VLBI
JARE	Japanese Antarctic Research Expedition (Japan)
JAXA	Japan Aerospace Exploration Agency (Japan)
JGN	Japan Gigabit Network (Japan)
JIVE	Joint Institute for VLBI in Europe
JPL	Jet Propulsion Laboratory (USA)
JSPS	Japanese Society for the Promotion of Science (Japan)
KSP	KeyStone Project (Japan)
KSRC	Kashima Space Research Center (Japan)
LAGEOS	LAser GEOdynamic Satellite
LAREG	Laboratoire de Recherches en Géodésie (France)
LBA	Long Baseline Array
LEA	Lab of Ephemeris Astronomy (Russia)
LEIF	Large Equipment and Infrastructure Funding
LLR	Lunar Laser Ranging
LNA	Low Noise Amplifier
LO	Local Oscillator
LOD	Length Of Day
LSB	Lower Side Band

LSGER	Lab of Space Geodesy and Earth Rotation (Russia)
MAO	Main Astronomical Observatory (Ukraine)
MBH	Mathews/Buffett/Herring Nutation Model
MIT	Massachusetts Institute of Technology (USA)
MLRO	Matera Laser Ranging Observatory (Italy)
MOBLAS	MOBile LASer
MODEST	MODel and ESTimate
MPI	Max-Planck-Institute (Germany)
MPIfR	Max-Planck-Institute for Radioastronomy (Germany)
MTLRS	Modular Transportable Laser Ranging System
NAOJ	National Astronomical Observatory of Japan (Japan)
NASA	National Aeronautics and Space Administration (USA)
NCAR	National Center for Atmospheric Research (USA)
NCEP	National Centers for Environmental Prediction (USA)
NEOS	National Earth Orientation Service (USA)
NESDIS	National Environmental Satellite, Data, and Information Service (USA)
NGS	National Geodetic Survey (USA)
NICT	National Institute of Information and Communications Technology (Japan)
NIPR	National Institute of Polar Research (Japan)
NMA	Norwegian Mapping Authority (Norway)
NNR	No-Net-Rotation
NNT	No-Net-Translation
NOAA	National Oceanic and Atmospheric Administration (USA)
NRAO	National Radio Astronomy Observatory (USA)
NRCan	Natural Resources Canada (Canada)
NTT	Nippon Telegraph and Telephone Corporation (Japan)
NVI	NVI, Inc. (USA)
OAN	Observatorio Astronómico Nacional (Spain)
OPAR	Paris Observatory (France)
OPC	(IVS) Observing Program Committee
OSO	Onsala Space Observatory (Sweden)
PF	Processing Factor
PIVEX	Platform Independent VLBI EXchange format
POLARIS	POLar motion Analysis by Radio Interferometric Surveying
PRARE	Precision RAnge and Range-rate Experiment
RAS	Russian Academy of Sciences (Russia)
RDV	Research and Development sessions using the VLBA
REPA	REsidual Plotting and Ambiguity resolution
RFI	Radio Frequency Interference
ROEN	Rádio-Observatório Espacial do Nordeste (Brazil)
RRFID	Radio Reference Frame Image Database
RTP	Real-Time Protocol
SAGE	Small Advanced Geodetic e-VLBI System
SEFD	System Equivalent Flux Density
SGL	Space Geodynamics Laboratory (Canada)

SHAO	Shanghai Astronomical Observatory (China)
SIMD	Single Instruction Multiple Data
SINEX	Solution INdependent EXchange format
SKA	Square Kilometer Array
SLR	Satellite Laser Ranging
SNAP	Standard Notation for Astronomical Procedures
SPbU	Saint-Petersburg University (Russia)
SPU	Saint-Petersburg University (Russia)
SRTM	Shuttle Radar Topography Mission
STDN	Satellite Tracking Data Network (NASA)
SWT	SW Technology (USA)
TAC	Totally Accurate Clock
TAI	Temps Atomique International (International Atomic Time)
TAO	Telecommunications Advanced Organization (Japan)
TDC	Technology Development Center
TECU	Total Electron Content Units
TEMPO	Time and Earth Motion Precision Observations
TOW	Technical Operations Workshop
TRF	Terrestrial Reference Frame
TUM	Technical University of Munich
UBB	Universidad del Bío Bío (Chile)
URSI	International Radio Science Union
USB	Upper Side Band
USNO	U. S. Naval Observatory (USA)
UT1	Universal Time
UTAS	University of Tasmania (Australia)
UTC	Coordinated Universal Time
VCS	VLBA Calibrator Survey
VERA	VLBI Exploration of Radio Astrometry
VLBA	Very Long Baseline Array (USA)
VLBI	Very Long Baseline Interferometry
VMF	Vienna Mapping Functions
VSSP	Versatile Scientific Sampling Processor
VTEC	Vertical Total Electron Content
VTRF	VLBI Terrestrial Reference Frame
WACO	WAshington COrrelator (USA)
WVR	Water Vapor Radiometer
WWW	World Wide Web
ZTD	Zenith Total Delay
ZWD	Zenith Wet Delay

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14. ABSTRACT
This volume of reports is the 2004 Annual Report of the International VLBI Service for Geodesy and Astrometry (IVS). The individual reports were contributed by VLBI groups in the international geodetic and astrometric community who constitute the components of IVS. The 2004 Annual Report documents the work of these IVS components over the period January 1, 2004 through December 31, 2004. The reports document changes, activities, and progress of the IVS. The entire contents of this Annual Report also appear on the IVS Web site at http://ivscc.gsfc.nasa.gov/publications/ar2004.

15. SUBJECT TERMS
Geodesy, astrometry, VLBI, geophysics, Earth orientation, very long baseline interferometry, interferometry, radio astronomy, geodynamics, reference frames, terrestrial reference frame, celestial reference frame, length of day, Earth system science, Earth rotation.

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